VALUING RESIDENTIAL ENERGY EFFICIENCY IN TWO ALASKA REAL ESTATE MARKETS: A HEDONIC APPROACH

By

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Abstract

Alaska households have high home energy consumption and expenditures. Improving the energy efficiency of the housing stock can reduce home energy consumption, thereby reducing home energy expenditures and CO_2 emissions. Improving the energy efficiency of a home may also increase its transaction price if the energy efficiency improvements are capitalized into the value of the home. The relationship between energy efficiency and transaction prices in the Fairbanks and Anchorage, Alaska residential real estate markets is examined.

Using a hedonic pricing framework and difference-in-differences analysis, the impact of the Alaska Home Energy Rebate program on the transaction prices of single-family homes in the Fairbanks and Anchorage housing markets from 2008 through 2015 is examined. The results indicate that compared to homes that did not complete the program, homes that completed the program sell for a statistically significant price premium between 15.1% and 15.5% in the Fairbanks market and between 5% and 11% in the Anchorage market.

A hedonic pricing framework is used to relate energy efficiency ratings and transaction prices of homes in the Fairbanks and Anchorage residential real estate markets from 2008 through 2015. The results indicate that homes with above-average energy efficiency ratings sell for a statistically significant price premium between 6.9% and 17.5% in the Fairbanks market and between 1.8% and 6.0% in the Anchorage market.

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Dedication

To my family for tolerating my absence

Chapter 1

Introduction

1.1 Introduction and Context

Households in Alaska are faced with a cold climate and relatively high energy prices leading to high home energy cost. In Alaska, average annual household energy costs are more than double the national average (AHFC, 2014). Homes located in cold climate regions[1] use more energy than homes located in regions with warmer climates (Sivak, 2013). The disparity in residential energy consumption is largely driven by the demand for space heating[2] (Considine, 2000). Homes in Alaska use nearly three times more energy per square foot than the national average (AHFC, 2014). Improving the energy efficiency of the housing stock may reduce the amount of energy needed to keep homes at a comfortable temperature, thereby reducing both household energy costs and CO_2 emissions (Boardman, 2010). In addition to reducing home energy costs, improving the energy efficiency of a home may increase its transaction price if the energy improvements are capitalized into the value of the home. The overarching purpose of this dissertation is to test the relationship between residential energy efficiency and transaction prices in the Fairbanks and Anchorage, Alaska real estate markets.

The Alaska economy follows the economic cycles of the petroleum industry. The vast majority of Alaska's unrestricted budget comes from oil taxes and royalties (Tichotsky, 2014). When oil prices are high, state revenue is high, leading to budget surpluses. However, high oil

[1] Cold climate region refers to regions that average 7,200 or greater heating degrees days annually which corresponds to the International Energy Conservation Code Climate Zone 6 (Green Building Advisor, 2017).
[2] Space heating is defined as, "heating of spaces especially for human comfort by any means (as fuel, electricity, or solar radiation) with the heater either within the space or external to it" (Merriam-Webster, 2017).

prices present a hardship for Alaska residents that use petroleum-based products to meet their energy needs. This is especially true in rural areas of the state where energy prices tend to be far higher than in the urban areas of the state due to difficult fuel delivery logistics, among other factors (Wilson et al., 2008). When oil prices spiked in 2008, it is estimated that rural households in the bottom income quintile were spending nearly 50% of their household income on space heating and electricity (Saylor et al., 2008). Households spending more than 10% of their income on home energy services (e.g., energy used for space heating, electricity, cooking, and domestic hot water) are considered to be in fuel poverty (Boardman, 2010). According to Boardman (2010), fuel poverty is the result of low incomes, high fuel prices, and an energy-inefficient housing stock. The three main policy options for reducing fuel poverty include increasing incomes, reducing fuel prices, and increasing the energy efficiency of the housing stock (Boardman, 2010).

In 2008, the Alaska Legislature appropriated $300 million to fund two residential energy efficiency programs in an effort to reduce high home energy costs by improving the energy efficiency of the housing stock. The Alaska Weatherization Assistance (Weatherization) program, a jointly state- and federally-funded residential energy efficiency program that provides residential energy efficiency upgrades at no cost to qualifying homeowners and renters meeting income requirements, received a $200 million appropriation (Goldsmith et al., 2012). An additional $100 million was appropriated to fund the Alaska Home Energy Rebate (Rebate) program, which was established by the legislature to incentivize homeowners to invest in residential energy efficiency improvements. The Rebate program was administered by the Alaska Housing Finance Corporation (AHFC) from 2008 through early 2016 when it was suspended due to state budgetary shortfalls (Brehmer, 2016). Through the Rebate program, homeowners could receive a rebate up to $10,000 for preapproved energy efficiency upgrades made to their primary residence (Goldsmith et al., 2012). Unlike the Weatherization program, the Rebate program did not have income requirements for participation. Both the Weatherization and Rebate programs required participating homeowners to undergo energy efficiency audits both before and after energy efficiency improvements were made to the home. During an energy audit, a home is assigned an energy efficiency rating on a scale ranging from 1 Star for the least energy efficient properties to 6 Stars for the most energy efficient properties.

Previous studies indicate that energy efficient homes command a price premium in many markets (Laquatra et al., 2002). The establishment of energy efficiency standards and certifications has made it possible to study the relationship between energy efficiency and real estate transaction prices. Domestically, much of the research on the value of residential energy efficiency in housing markets has focused on the impact of the U.S. Environmental Protection Agency's Energy Star program and the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification (Bruegge et al., 2016; Kahn and Kok, 2014; Walls et al., 2016). Much of the research on the value of energy efficiency in European housing markets is focused on Energy Performance Certificates, which must be made available for any property built, rented or sold in European Union (E.U.) member nations since the passage of the 2003 E.U. Energy Performance of Buildings Directive (Chegut et al., 2016; Davis et al., 2015; Hyland et al., 2013).

In Alaska, the Rebate program provides an opportunity to investigate how energy efficiency retrofits affect the transaction prices of residential properties. Although the specific energy efficiency improvements made to individual homes are unknown, all homes that completed the Rebate program underwent an energy efficiency retrofit. Additionally, the energy audits conducted for Rebate and Weatherization program participants provide an opportunity to investigate the relationship between the energy efficiency rating of homes and their transaction prices.

1.2 Hedonic Pricing Framework

The hedonic pricing framework is commonly used in studies on real estate markets (Laquatra et al., 2002). A house is a composite good made up of its constituent characteristics. The hedonic pricing framework relates the transaction price of a home to its constituent characteristics:

$$P = f(S, L, E) \qquad (1.1)$$

Where S represents a property's structural characteristics (e.g., bedrooms, bathrooms, square footage, etc.), L represents a property's locational characteristics (e.g., neighborhood, school district, proximity to town center, etc.), and E represents a property's environmental characteristics (e.g., air quality, water quality, noise level, etc.) (Rosen, 1974). Partially differentiating Eq. 1.1 with respect to a given characteristic yields the marginal implicit price of that characteristic. In this manner, the hedonic pricing framework allows the transaction price of a property to be deconstructed and the contribution of each characteristic to be isolated. The hedonic pricing framework is used in this dissertation to isolate the contribution of energy efficiency to transaction prices of homes in the Fairbanks and Anchorage residential real estate markets. The marginal implicit price associated with the energy efficiency of a home measures the price premium or discount placed on energy efficiency.

The main criticism of the hedonic pricing framework is that hedonic models are sensitive to the functional form selected, yet the underlying economic theory gives no guidelines on selecting a functional form (Chau and Chin, 2003). The types of functional forms used for hedonic models in the literature include linear, semi-log, log-log, and Box-Cox transformation. The semi-log functional form is the most prevalent functional form in the literature because of the ease of interpreting the coefficients, the ability to include indicator variables, and the reduction of variance in the errors (Xiao, 2017). Other common criticisms of the hedonic pricing framework include the large amount of data required to estimate models and potential misspecification from either including irrelevant variables or omitting relevant variables due to missing data.

1.3 Data

Data on single-family residential property transactions from 2008 through 2015 are from the Alaska Multiple Listing Service. The data include the transaction price of the property, the date of the transaction, the physical addresses of the property, the MLS area number, the property tax parcel number, the year of construction, and the physical characteristics of the property (e.g. square footage, number of bathrooms, number of bedrooms, garage capacity, acreage, etc.). Data on Rebate and Weatherization program participants were obtained from the Cold Climate Housing Research Center, which maintains the Alaska Retrofit Information System database on behalf of the AHFC. The data include the physical addresses of participant properties, the dates of the as-is and post-improvement energy efficiency audits, and the as-is and post-improvement energy ratings. The property tax parcel number for the physical addresses of Rebate and Weatherization program participant properties were obtained from the Fairbanks North Star Borough and Municipality of Anchorage property tax databases and were used to merge the Alaska MLS and Rebate/Weatherization program participant datasets.

Any property without a transaction price was removed from the dataset. Properties without plumbing, known as dry cabins, were also removed from the dataset because they belong to a different market segment. For Chapters 2 and 3, Weatherization program participants and Rebate participants that began, but did not complete the Rebate program were removed from the dataset because these homes underwent partial or complete energy efficiency retrofits and are therefore inappropriate to include in the control group.

1.4 Research Questions

There are three main research questions addressed in this dissertation.

1. Does Rebate program participation affect the transaction prices of homes in the Fairbanks market?
    - H_0: Rebate program participation has no effect on the transaction prices of homes in the Fairbanks market.
    - H_A: Rebate program participation has an effect on the transaction prices of homes in the Fairbanks market.
2. Does Rebate program participation affect the transaction prices of homes in the Anchorage market?
    - H_0: Rebate program participation has no effect on the transaction prices of homes in the Anchorage market.
    - H_A: Rebate program participation has an effect on the transaction prices of homes in the Anchorage market.

3. Do the energy efficiency ratings of residential properties affect their transaction prices in the Fairbanks and Anchorage markets?
    - H_0: Energy efficiency ratings have no effect on the transaction prices of residential properties in the Fairbanks and Anchorage markets.
    - H_A: Energy efficiency ratings have an effect on the transaction prices of residential properties in the Fairbanks and Anchorage markets.

1.5 Contribution of Research

This research contributes to the larger body of work investigating the value of energy efficiency in residential property markets. More specifically, this research adds to the limited body of work investigating the value of residential energy efficiency in cold climate regions (Cerin et al., 2014; Fuerst et al., 2016; Harjunen and Liski, 2014; Mandell and Wilhelmsson, 2011). To date, no research has been conducted to investigate the value of energy efficiency in Alaska residential real estate markets. This is the first study conducted on the impact of the Rebate program on residential property prices in Alaska. This is also the first study to investigate the relationship between residential energy efficiency ratings and transaction prices of homes in Alaska.

The results of this research provide information on the value Fairbanks and Anchorage residents place on residential energy efficiency. These results are useful to Alaska policymakers responsible for shaping residential energy policy and are also useful to Fairbanks and Anchorage residents who are either interested in purchasing an energy efficient home or are interested in making energy efficiency improvements to an existing home.

While the main focus of this dissertation is the value placed on residential energy efficiency, estimates of CO_2 emission reductions and energy cost savings stemming from energy efficiency improvements are also calculated. A single home may not produce a remarkable quantity of CO_2, but the residential sector as a whole does. Twenty percent of annual CO_2 emissions in the United States are emitted from the residential sector (Energy Information Administration, 2016). Residential energy efficiency programs such as the Weatherization program and Rebate program aid in reducing CO_2 emissions from the housing sector, which is important because of the link between CO_2 emissions and global climate change.

In addition to the role energy efficiency programs play in reducing residential sector CO_2 emissions, these programs also reduce the percentage of household budgets dedicated to energy costs. Energy prices are cyclical. A reduction in energy prices can lift a household out of fuel poverty, but without energy efficiency improvements to the home, the household will descend back into fuel poverty should energy prices increase again. Improving the energy efficiency of a home means that less energy is required to heat a home to comfortable temperature regardless of the price of energy which makes household budgets less vulnerable to spikes in energy prices.

Although this dissertation is focused on two housing markets in Alaska, the results can be applied more broadly to other cold climate regions. Energy efficiency programs that serve cold climate regions can have large impact on both CO_2 emissions and energy cost savings because households located in cold climate regions tend to use more energy than households located in regions with warmer climates. Therefore, even modest improvements in the energy efficiency of the housing stock across cold climate regions can add up to significant reductions in energy use, CO_2 emissions, and fuel poverty over time.

1.6 Chapter Overview

In Chapter 2, the impact of completing the Rebate program on transaction prices of single-family homes in the Fairbanks real estate market from 2008 through 2015 is explored using the hedonic pricing framework. Hedonic models are estimated using both the full sample of all home sales over the study period and a subsample of control properties matched to Rebate homes based on their observable attributes using propensity score matching. The results indicate that in the Fairbanks market, compared to homes that did not complete the Rebate program, homes that completed the Rebate program sell for a price premium between 15.5% when the model is estimated with the full sample and 15.1% when the model is estimated with the propensity score matched sample.

In this chapter, emphasis is placed on the energy cost savings resulting from residential energy efficiency improvements. Households in Fairbanks have home energy costs nearly four times above the national average (AHFC, 2014). Reducing household energy costs through energy efficiency improvements can lift households out of fuel poverty and reduce strain on household budgets. Households spending a smaller portion of their income on home energy costs can reallocate those funds to other goods and services.

In Chapter 3, the impact of completing the Rebate program on transaction prices of homes in Anchorage market from 2008 through 2015 is explored using the hedonic pricing framework. Hedonic models are estimated using both the full sample of all transactions and a propensity score matched sample. The results of the hedonic models indicate that in the Anchorage market, compared to homes that did not complete the Rebate program, homes that completed the Rebate program sell for a price premium between 11% when the model is estimated with the full sample and 10% when the model is estimated with the matched sample. In addition to the hedonic models, a difference-in-differences (DiD) model is estimated using a sample of homes that sold at least twice over the study period. DiD models are used in policy analysis to study the differential effect of a policy on a treatment group and a control group. The results of the DiD model indicate that homes in the Anchorage market that selected into the Rebate program were, on average, worth 5% more at the time of their first sale than homes that did not select into the Rebate program. After controlling for price differences at the time of the first sale and the price appreciation trend in the market between the first and second sales, the results indicate that in the Anchorage market, homes that completed the Rebate program sell for a 5% premium over similar homes that did not complete the program.

In this chapter, emphasis is placed on CO_2 emission reductions resulting from energy efficiency improvements. Because Anchorage is Alaska's most populous city with nearly 40% of the state's population residing there, improving the energy efficiency of the housing stock in Anchorage can substantially reduce CO_2 emissions from Alaska's residential sector. It is estimated that households that complete the Rebate program reduce their CO_2 emissions by an average of 10,565 pounds annually (Information Insights, 2009). Therefore, fuel savings resulting from energy efficiency improvements made to the housing stock through Rebate program participation reduce annual CO_2 emissions from the Anchorage residential sector by over 60,000 metric tons.

In Chapter 4, the relationship between the energy efficiency ratings of single-family residential properties and their transaction prices in the Anchorage and Fairbanks markets is explored using the hedonic pricing framework. The sample consists of homes that eventually participated in either the Weatherization or Rebate programs. Homes that sold before the date of their as-is energy audit are assigned their as-is energy rating. Homes that sold after the date of their post-improvement energy audit are assigned their post-improvement energy rating. Hedonic models are estimated separately for the Anchorage and Fairbanks housing markets. In the Anchorage market, homes with above-average energy efficiency ratings sell for a price premium between 1.8% and 6.0%, whereas homes with below-average energy efficiency ratings sell for a discount between 1.3% and 7.4%. In the Fairbanks market, homes with above-average energy efficiency ratings sell for a price premium between 6.9% and 17.5%, whereas homes with below-average energy efficiency ratings sell for a discount between 5.0% and 13.3%.

In this chapter, emphasis is placed on the importance of energy efficiency ratings as a means of reducing information asymmetry between buyers and sellers in the residential real estate market. Energy efficiency ratings provide a standardized metric for signaling the energy efficiency of properties. Energy efficiency ratings allow buyers to estimate annual energy costs associated with occupying a home. Energy efficiency ratings are useful to the sellers of energy efficiency properties because, in theory, buyers should be willing to pay a price premium for more energy efficient properties since occupying energy efficient properties saves their occupants money on annual energy costs compared to similar properties that are less energy efficient.

Chapter 5 is the conclusion. A summary of each chapter is provided followed by a general discussion regarding residential energy efficiency. Then the contributions and limitations of the research are discussed followed by recommendations for future research and a brief conclusion.

1.7 References

AHFC (Alaska Housing Finance Corporation), 2014. Alaska Housing Assessment. https://www.ahfc.us/efficiency/research-information-center/housing-assessment/ (accessed 30.01.17).

Boardman, B., 2010. Fixing fuel poverty: Challenges and solutions. Earthscan, New York.

Brehmer, E., 2016. Budget deficit hits state energy programs, rebates cut. Alaska Journal of Commerce. http://www.alaskajournal.com/2016-03-02/budget-deficit-hits-state-energy-programs-rebates-cut#.V-czn6L-R4O (accessed 01.09.16).

Bruegge, C., Carrión-Flores, C., Pope, J.C., 2016. Does the housing market value energy efficient homes? Evidence from the energy star program. Regional Science and Urban Economics 57(2016), 63-76.

Cerin, P., Hassel, L.G., Semenova, N., 2014. Energy performance and housing prices. Sustainable Development 22, 404-419.

Chau, K.W., Chin, T.L., 2003. A critical review of the literature on the hedonic price model. International Journal for Housing Science and Its Applications 27(2), 145-165.

Chegut, A., Eichholtz, P., Holtermans, R., 2016. Energy efficiency and economic value in affordable housing. Energy Policy 97, 39-49.

Considine, T.J., 2000. The impacts of weather variations on energy demand and carbon emissions. Resource and Energy Economics 22 (4), 295-314.

Davis P.T., McCord, J., McCord, M.J., Haran, M., 2015. Modeling the effect of energy performance certificate rating on property value in the Belfast housing market. International Journal of Housing Markets and Analysis 8(3), 292-317.

Energy Information Administration, 2016, October. Monthly energy review.

Fuerst, F., Oikarinen, E., Harjunen, O., 2016. Green clientele effects in the Helsinki metropolitan area housing market. City of Helsinki Urban Facts Working Papers 2016:3.

Goldsmith, S., Pathan, S., Wiltse, N., 2012. Snapshot: the home energy rebate program. Institute of Social and Economic Research, University of Alaska Anchorage. http://cchrc.org/docs/snapshots/HERP_snapshot.pdf (accessed 13.09.16).

Green Building Advisor, 2017. Building science: All about climate zones. http://www.greenbuildingadvisor.com/blogs/dept/building-science/all-about-climate-zones (accessed 07.03.17).

Harjunen, O., Liski, M., 2014. Not so myopic consumers – evidence of capitalisation of energy technologies in a housing market. CESifo Working Paper Series, No. 4989.

Hyland, M., Lyons, R.C., Lyons, S., 2013. The value of domestic building energy efficiency: Evidence from Ireland. Energy Economics 40, 943-952.

Information Insights, 2009. Alaska housing assessment: Part I and II. http://www.cchrc.org/docs/reports/TR_2009_02_2009_AK_Housing_Assessment_Final.pdf (accessed 01.09.16).

Kahn, M.E., Kok, N., 2014. The capitalization of green labels in the California housing market. Regional and Urban Economics 47 (2014) 25-34.

Laquatra, J., Dacquisto, D.J., Emrath, P., Laitner, J.A., 2002. Housing market capitalization of energy efficiency revisited. ACEEE Summer Study of Energy Efficiency in Buildings, Teaming for Efficiency, Proceedings 8.

Mandell, S., Wilhelmsson, M., 2011. Willingness to pay for sustainable housing. Journal of Housing Research 20 (1), 35-51.

Merriam-Webster, 2017. Definition of space heating. https://www.merriam-webster.com/dictionary/space%20heating (accessed 13.03.17).

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy 82 (1), 34-55.

Saylor, B., Haley, S., Szymoniak, N., 2008. Estimated household costs for home energy use, May 2008. Institute of Social and Economic Research, University of Alaska Anchorage. http://www.iser.uaa.alaska.edu/Publications/webnote/LLFuelcostupdatefinal.pdf (accessed 21.09.16).

Sivak, M., 2013. Air conditioning versus heating: climate control is more energy demanding in Minneapolis than Miami. Environmental Research Letters 8 (1), 1-4.

Tichotsky, J., 2014. Alaska state revenues: overview, history, and forecast Alaska department of revenue forum on Alaska's fiscal future October 4, 2014. http://akcommonground.org/wp-content/uploads/2014/10/Tichotsky-John-Alaska-State-Revenues-for-Oct-4-2014-Fiscal-Future-Forum.pdf (accessed 07.08.16).

Walls, M., Palmer, K., Gerarden, T., Bak, X., 2016. Is energy efficiency capitalized into home prices? Evidence from three U.S. cities. Resources for the Future, working paper.

Wilson, M., Salor, B., Szymoniak, N., Colt, S., Fay, G., 2008. Dollars of difference: What affects fuel prices around Alaska?, May 2008. Institute of Social and Economic Research, University of Alaska Anchorage. https://www.uaf.edu/files/ces/energyconservation/WhatAffectsFuelPricesInAlaska.pdf (accessed 04.02.17).

Xiao, Y., 2017. Urban Morphology and Housing Market. Springer, Singapore.

Chapter 2

The Value of Residential Energy Efficiency in Interior Alaska: A Hedonic Pricing Analysis[1]

Abstract

Residents of Interior Alaska are faced with a cold climate and relatively high energy prices which results in high home energy expenditures. Increasing the energy efficiency of the housing stock can help reduce household energy expenditures. Following a spike in oil prices in 2008, legislation was passed which created the Home Energy Rebate Program. Homeowners participating in the program were eligible to receive up to a $10,000 rebate for preapproved home energy efficiency improvements. This paper examines the effect of the Home Energy Rebate program on the selling prices of single-family residences in the Fairbanks North Star Borough from 2008 through 2015 using a hedonic pricing analysis. The results show that homes that participated in the Home Energy Rebate program in the Fairbanks North Star Borough sell for a 15.1% to 15.5% price premium over similar homes that did not participate in the program which indicates that investments in residential energy efficiency are compensated. This is the first study to examine the impact of energy efficiency on house prices in a market with a subarctic climate.

2.1 Introduction

Energy inefficient homes are expensive to heat because more energy is required to maintain a comfortable indoor temperature due to heat escaping through the building fabric.

[1] Pride, D., and Little, J., 2017. The Value of Residential Energy Efficiency in Interior Alaska: A Hedonic Pricing Analysis. Prepared for submission to Energy Policy.

Residents of Fairbanks, Alaska have home energy expenditures nearly four times greater than the national average due to the combination of relatively high energy prices, the subarctic climate, and an aging housing stock (AHFC, 2014). Residential energy efficiency improvements can help reduce home energy costs, but these improvements are often expensive to undertake. For example, the average cost of replacing a boiler for an average-sized home in Fairbanks is nearly $14,000 (Meyer et al., 2011).

The cost associated with residential energy efficiency improvements may serve as a deterrent for some homeowners. Following the oil price spike of 2008, policymakers in Alaska recognized this problem and passed legislation creating the Home Energy Rebate (Rebate) program. The primary policy objective of the program was to reduce residential energy costs by incentivizing homeowners to invest in energy efficiency improvements. The program provided participating homeowners with up to a $10,000 rebate for preapproved energy efficiency improvements. The program operated from 2008 through early 2016 when it was suspended due to state budgetary shortfalls.

In addition to reducing home energy expenditures, energy efficiency improvements may increase the selling price of a home. A potential buyer in the market for a home should be willing to pay an energy efficiency premium either equal to or less than the present value of the expected energy savings over the buyer's anticipated tenure in the home. Prior studies have found a positive relationship between the energy efficiency of a property and its transaction price (Laquatra, et al., 2002; Nevin and Watson, 1998).

This study is the first to estimate the impact of the Rebate program on house prices in Alaska, and also the first study on whether energy efficiency measures are capitalized into house prices in a market with a subarctic climate. This is important because households in cold climates use more energy than households in warmer climates (Sivak, 2013). The disparity in residential energy use can largely be attributed to demand for space heating (Considine, 2000). In Fairbanks, approximately 80% of total residential energy use is dedicated to space heating, compared to the national average of 42% (Alaska Energy Authority, 2012; Energy Information Administration (EIA), 2013).

Drawing on transactions data from 2008 to 2015, the effect of the Rebate program on transaction prices of single-family homes the Fairbanks North Star Borough (Fairbanks) is assessed using the hedonic pricing framework. Identifying properties that participated in the Rebate program provides an opportunity to investigate the impact of energy efficiency improvements on home prices in Fairbanks. Although the specific energy efficiency measures undertaken by program participants are not known[2], all Rebate program participants completed energy efficiency retrofits. While this study is specifically about the price premium resulting from participation in the Rebate program, these results may be more generally applicable to all residential properties that have received energy efficiency retrofits within Fairbanks. The use of a hedonic model allows for the estimation of the marginal price for energy efficiency improvements to be isolated.

The remainder of the paper is structured as follows: Section 2.2 reviews the previous literature. Section 2.3 provides background information on the study area, the impact of the oil price spike of 2008 and the Rebate program. The methods and regression model are described in

[2] The data provided by the Cold Climate Housing Research Center did not state the specific energy efficiency improvements made by Rebate program participants.

section 2.4. Section 2.5 describes the data used in the analysis, followed by the results in section 2.6. The conclusion and policy implications are covered in section 2.7.

2.2 Literature Review

There is a growing body of literature examining the effect of energy efficiency on property sale and rent prices using the hedonic regression analysis framework. One of the earliest studies on the subject examined whether the fuel savings resulting from energy efficiency improvements are capitalized into housing values in Des Moines, Iowa (Dinan and Miranowski, 1989). Using a sample of 234 detached homes, the authors find that for each $1 decrease in the level of fuel expenditures required to keep a home at 65°F, the expected value of the selling price of a home increased by $11.63. Many subsequent studies focused on commercial properties (Wiley et al., 2010; Eichholtz et al., 2010; Fuerst and McAllister, 2011; Reichardt et al., 2012). More recently, there has been an increase in the literature concentrating on residential properties.

Recent studies regarding how energy efficiency affects property prices in the United States are mainly focused on the Energy Star and LEED certification programs (Bruegge et al., 2016; Walls et al., 2016; Bond and Devine, 2016). The U.S. Environmental Protection Agency introduced the Energy Star certification program for newly constructed residential properties in 1995 so that homebuyers could identify properties that were more energy efficient than standard non-certified homes (Energy Star, 2016). Leadership in Energy and Environmental Design (LEED) is a green building certification program developed by the U.S. Green Building Council in 1998 that includes a set of rating systems for the design, construction, operation, and maintenance of green buildings (Indiana University Bloomington, 2016).

Using a sample of homes across three metropolitan areas including the Research Triangle region of North Carolina, Portland, Oregon, and Austin, Texas, Walls et al. (2016) explore whether energy efficiency is capitalized into home values in these markets. Both the national Energy Star program and local green certification programs are investigated. In Portland and the Research Triangle area, the Energy Star certification is associated with a 2% price premium. In Austin, the local green certification is associated with a 7% to 8% price premium, but the Energy Star certification is not associated with a premium. The authors suggest this may be because Austin's local green certification program requirements are more stringent than the certification requirements of the national Energy Star program. In Portland, properties with the local green certification sell for a premium of 3% over similar non-certified properties.

Bruegge et al. (2016) investigate the impact of Energy Star program certifications on the value of single-family residential properties in Gainesville, Florida. Using a sample of 5,528 home sales from 1997 through 2009, they find that homeowners are willing to pay a price premium of 1.2% for new Energy Star certified homes but this premium decreases over subsequent sales of the property. In addition to the traditional hedonic technique, the authors also employ a modified repeat sales index to investigate the rate of depreciation for Energy Star certified homes and find the rate of depreciation between sales to be 0.4%, compared to a rate of depreciation of 1.3% found using the cross-sectional hedonic model.

Bond and Devine (2016) focus on the impact of LEED certification on the rent of multifamily properties across the United States. The authors find a premium of approximately 8.9% in rent prices associated with LEED certified properties compared to non-certified properties. The authors also find that green, non-LEED properties command a 7.6% rent premium over non-green properties.

Many of the recent studies focusing on European housing markets examine the impact of energy performance certificates (EPC) on residential property prices following the implementation of the EU Energy Performance of Buildings Directive in various European countries (Chegut et al., 2016; de Ayala et al., 2016; Cerin et al., 2014; Fuerst et al., 2016). The 2003 EU Energy Performance of Buildings Directive established a common methodology for the calculation of a building's energy efficiency across member states (EUR-Lex, 2007). The directive requires EPCs to be made available when buildings are constructed, sold, or rented.

Chegut et al. (2016) investigate the impact of energy efficiency on the value of homes on the affordable housing market in the Netherlands. Using a sample of 17,835 homes sold from 2008 through 2013, the authors find that dwellings with high energy efficiency, as documented by energy performance certificates, sell for a premium of 2.0% to 6.3% compared to similar dwellings with lower energy efficiency ratings. For Spanish housing markets, de Ayala et al. (2016) use survey data collected from 1,507 households to examine the impact of energy efficiency ratings on home prices. The authors find that energy efficient dwellings sell for a price premium between 5.4% and 9.8% compared to similar properties with lower energy efficiency ratings.

There are multiple studies that examine residential energy efficiency and home prices in cold climate regions. Cerin et al. (2014) examine whether mandatory energy performance certificates affected property price premiums in Sweden after the EU Energy Performance of Buildings Directive was implemented. Using a sample of over 16,000 housing transactions from 2009 through 2010 across Sweden, the authors find that a 1% increase in the energy performance of a property was associated with a modest .06% increase in the transaction price of the property. Mandell and Wilhelmsson (2011) use home sales in Stockholm, Sweden to investigate the willingness to pay for environmentally-friendly attributes. The authors find that homebuyers have a positive willingness to pay for home attributes that reduce energy and water consumption.

Harjunen and Liski (2014) consider the impact of electric heating and district heating[3] on single-family housing prices in the Finnish cities of Helsinki, Espoo, and Vantaa. The authors find that homebuyers are willing to pay a 6% premium for district heating over electric heating. The price premium is very similar to the capitalized energy savings resulting from the use of district heating over electric heating. Using a sample of apartment transactions in Helsinki from 2009 through 2012, Fuerst et al. (2016) investigate the impact of energy ratings on housing prices. The authors find that apartments with the highest three energy ratings are associated with a price premium of 3.3%. However, when detailed neighborhood characteristics are included in the model specification, the premium drops to 1.5%.

2.3 Background

2.3.1 Study Area

Fairbanks which is located in the Interior region of Alaska is the study area (See Figure 2.1). The borough has a land area of over 7,300 square miles and a population of approximately 98,000 residents (U.S. Census Bureau, 2015). The City of Fairbanks is the largest city in the borough with approximately 32,000 residents. Fairbanks has a subarctic climate characterized by long, cold winters which typically last from mid-October to mid-April and short, warm summers. The city has an average annual temperature of -2.4° C (27.7° F) (Alaska Climate Research Center (ACRC), 2016). It is not uncommon for the temperature to fall to -40° C (-40°F) during the winter months. Fairbanks is located approximately 200 miles south of the Arctic Circle at

[3] District heating is defined as, “the distribution of heat by steam or otherwise from a central plant to buildings more or less widely distributed” (Merriam-Webster, 2017).

latitude 64.8 degrees north. The high latitude of the city results in extreme fluctuations in daylight hours across the seasons. On the summer solstice, Fairbanks receives nearly 22 hours of sunlight, while on the winter solstice the city receives fewer than four hours of sunlight.

Residential energy consumption is highest in the winter months when demand for heating and electricity are at their greatest. As the outdoor temperature drops, heating degree days[4] increase and more energy is required to heat a home to a comfortable level. In 2015, Fairbanks had 13,669 heating degree days (ACRC, 2016). By comparison, the region of New England had 6,524 heating degree days (EIA, 2016a). The average home in Fairbanks uses 150.7 MBtu per year for space heating compared to 85.4 MBtu per year in New England [5] (Information Insights, 2009). This translates into the equivalent of 1,084 gallons of heating oil for Fairbanks versus 614 gallons for New England, a difference of 470 gallons. Although homes in Fairbanks use more energy overall for heating than homes in New England, homes in Fairbanks use approximately 15% less fuel per heating degree day than homes in New England suggesting that the housing stock in Fairbanks is more energy efficient than the housing stock in the New England region.

In addition to climate, residential energy consumption also depends on the size, condition and age of a home. A less energy efficient home will require more energy to maintain a comfortable temperature than a more energy efficient home of the same size. Alaska is one of nine states that do not have a statewide mandatory residential building energy code (DOE, 2017). However, the state does have voluntary energy efficiency certification program, the Building Energy Efficiency Standard (BEES) (U.S. Department of Energy, 2016). BEES came into effect in 1992. Any home built after 1991 must be in compliance with the version of BEES that was in

[4] Heating degree days are the annual sum of the difference between the average outdoor air temperature over a 24-hour period and a base temperature (typically 65°F) (EIA, 2015).
[5] A British thermal unit (Btu) is the amount of work required to raise a pound of water one degree Fahrenheit.

effect at the time of its construction in order to qualify for financing through the Alaska Housing Financing Corporation[6] (AHFC).

The energy performance of newer homes in the Fairbanks housing stock is superior to older homes. On average, homes built in Fairbanks since 2005 use 35% less energy than homes built in the borough during the 1970s (AHFC, 2014). Nearly 75% of the housing stock in Fairbanks is over 25 years old and, more than half of the homes in Fairbanks were built in the 1970s and 1980s during the residential construction boom associated with the building of the Trans Alaska Pipeline System.[7] Many of these homes were built without regard for the local climate since many builders were from out-of-state and were accustomed to building homes to standards appropriate for warmer climates. In an area with a subarctic climate, an energy inefficient home will cost more to heat than the same home would cost to heat in a temperate climate. As heat escapes through the building envelope, more energy is required to raise the indoor temperature to a constant temperature in a colder climate than in a temperate climate because there is a greater difference between the outdoor temperature and the desired indoor temperature.

Residential energy prices are relatively high in Fairbanks. In 2014, the average annual residential energy costs[8] in Fairbanks were estimated to be $8,110, which is 3.8 times above the national average (AHFC, 2014). This is in part due to borough residents' heavy reliance on heating oil for space heating. Nearly 73% of households in Fairbanks use heating oil as their primary fuel for space heating (Sierra Research, 2015). In Alaska, heating oil is typically more

[6] The Alaska Housing Finance Corporation is a public corporation that provides affordable loans for housing and administers public and senior housing programs as well as energy efficiency and weatherization programs.
[7] The Trans Alaska Pipeline System is a nearly 800 mile pipeline and associated pump stations that transports crude oil from the oil fields of the North Slope to Valdez, Alaska.
[8] Residential energy costs include costs related to space heating, cooking, domestic hot water, and electricity used for lighting and appliances.

expensive per Btu than other fuels commonly used for space heating such as wood and natural gas. However, heating oil is less costly per Btu than heating with electric because electricity rates in Fairbanks are more than 1.5 times above the national average. (EIA, 2016b; GVEA, 2016).

2.3.2 Oil Price Spike of 2008

Alaska's state economy follows the boom and bust cycles of the oil industry. From 2005 through 2014, nearly 90% of the state's unrestricted budget came from oil revenue (Hobson, 2016). When oil prices are high, there is ample revenue to fund the state budget. The state collected over $11 billion in petroleum revenue in fiscal year 2008 (Tichotsky, 2014). While high petroleum prices are good for state revenue, they present a hardship for Alaska residents who rely on petroleum-based products to meet their energy needs. The rapid increase in oil prices disproportionately impacted households relying on heating oil for space heating. In June of 2008, the average price of a gallon of heating fuel oil in Alaska was $5.51 (Alaska Division of Regional and Community Affairs, 2008). The price spike was more pronounced in remote, rural areas[9] of the state where fuel prices were as high as $9.10[10] per gallon. During this time, it was estimated that households in rural areas with the lowest 20% of incomes were spending nearly half of their household income on residential space heating and electricity (Saylor et al., 2008).

As energy prices climbed, state policymakers looked to ease the burden of high home energy costs on Alaska residents. Three policy approaches are typically used to reduce the burden of high energy prices on households; these include increasing incomes through transfer

[9] Many rural communities do not have access to a connected road system. These communities must have fuel barged in during the ice-free months of the year or flown in by plane. The complicated delivery logistics and delivery charges increase the price of fuel.
[10] The price of heating fuel #1 in Kokhanok, Alaska was $9.10 per gallon in June 2008.

payments, reducing the price of energy through subsidies, and improving the energy efficiency of the housing stock through residential energy efficiency programs (Boardman, 2010).

Income transfers and energy subsidies must be perpetually allocated in order to reduce the household energy cost burden, and these measures provide no incentive to reduce energy consumption (Boardman, 2010). Of the three aforementioned policy approaches, increasing the energy efficiency of the housing stock is the longest-lasting approach to reducing the burden of energy prices on households and the most sustainable from both an environmental and budgetary perspective (Buildings Performance Institute Europe, 2014; Boardman, 2010; Roberts, 2008). Once a home undergoes measures to improve its energy efficiency, the home should require less energy regardless of energy prices, and the energy efficiency improvements should last for at least several years (Boardman, 2010; Kontonasiou et al., 2015).

To improve the energy efficiency of the housing stock across the state, the legislature appropriated $300 million in 2008 for two residential energy efficiency programs (Alaska Journal of Commerce, 2008). The Alaska Weatherization Program, a jointly state- and federally-funded program to improve the energy efficiency of dwellings for renters and homeowners with incomes below the regional median household income, received a $200 million appropriation (Goldsmith et al., 2012). Federal funding for the Weatherization program is based on state population. Alaska receives approximately $1 to $1.5 million annually for the Weatherization program (Anderson, 2015). For homeowners who did not qualify for the Weatherization program, the legislature established the Rebate program and appropriated $100 million to fund the program. Table 2.1 displays the annual state appropriations for both the Rebate and Weatherization programs.

Between 2008 and 2015, nearly 25,000 homeowners across the state participated in the Rebate program and received an average rebate $6,389 (Ord, 2015). It is estimated that, on average, program participants reduced their annual home energy costs by 30% and reduced their CO_2 levels by 35% (Information Insights, 2009).

2.3.3 Home Energy Rebate Program

The Rebate program was a state-funded program administered by the AHFC that provided participants with a rebate up to $10,000 for preapproved energy efficiency improvements to their residence (AHFC, 2013). The program was active from May 2008 through March 2016 when the AHFC announced that the Rebate program would no longer accept applications for the program due to state budgetary shortfalls (Brehmer, 2016). The oil price increases which had initially provided the state revenue needed to fund the program were countered by steep decreases in oil prices in 2015. Lower oil prices reduced state revenue and led to the suspension of the program.

Program participants paid upfront for eligible energy efficiency improvements and were reimbursed afterward with a rebate. The program did not have any income restrictions for participation. To be eligible for the program, the participant had to be the owner and occupier of the residential dwelling, and the dwelling had to be the participant's primary residence. A property could only go through the program once. Participating homes that sold were not eligible to participate again under a new owner.

Homeowners wishing to participate were required to sign up for the program and be placed on a waiting list to receive an energy rating. Participants were required to have both a pre- and post-improvement rating; AHFC provided reimbursement up to $325 for the initial as-is energy rating before any improvements were made and up to $175 for the post-improvement energy rating after the improvements were completed.

During the as-is rating an AHFC-approved energy auditor completed the on-site energy rating using the agency's home energy modeling software, AkWarm, to assess the energy efficiency of the home. The auditor then generated an Energy Efficiency Improvement Options Report specific to the dwelling that listed various approved energy efficiency measures and the estimated total cost, estimated total savings, simple payback period, and savings to investment ratio for each listed measure. Only the improvements listed in the Energy Efficiency Improvement Options Report were eligible for reimbursement through the Rebate program, but homeowners were able to choose which of the listed options to complete. The homeowner then had 18 months from the date of the audit to complete the pre-approved energy efficiency improvements, undergo a post-improvement energy audit, and submit required documentation to AHFC to receive the rebate. The required documentation included the Post-Improvement Rating Certificate stating the home's post-improvement energy rating, copies of receipts for labor and materials and proofs of payment for the eligible improvements, and the energy rater's invoice and proof of payment for the audit.

The energy rating of the home was based on a system of energy rating points and stars (See Table 2.2). A home's energy rating can range from 1 Star to 6 Stars. A step increase in a home's energy rating results in moving up the energy efficiency rating scale from one star to the next higher star. The final amount of a participant's rebate was determined by eligible receipts and the improvement of the home's energy efficiency rating between the as-is rating and the post-improvement rating. The maximum possible rebate amounts for step increases are shown in Table 2.3.

2.4 Methods

A hedonic pricing framework is used to estimate the price premium associated with participating in the Rebate program for residential homes in Fairbanks. Hedonic models are commonly used in studies on real estate markets. In the hedonic method, price differentials are driven by the characteristics of the good in question. As the vector of characteristics changes, price differentials are observed, these price changes are then used to estimate an implicit price for each attribute (Rosen, 1974). In this instance, the implicit price associated with Rebate program participation measures the premium placed on that attribute of the home.

2.4.1. Regression Model

The semi-log hedonic price model relating the logarithm of the transaction price of a property to its physical characteristics, geographic location, time of sale, and participation status in the Rebate program is estimated using pooled OLS.

$$Ln(price_i) = \alpha + \beta X_i + \sum_{j=1}^{11} \gamma_j A_j + \sum_{k=1}^{7} \delta_k Y_k + \sum_{m=1}^{3} \zeta_m Q_m + \psi r_i + \varepsilon_i \quad (2.1)$$

In Eq. 2.1 the dependent variable $Ln(price_i)$is the log of the transaction price of home *i*; α is a constant term; X_i is a vector of characteristics for home *i*, including square footage (*Square feet*), number of bedrooms (*Bedrooms*), number of bathrooms (*Bathrooms*), garage car capacity (*Garage Capacity*), a indicator variable for a heated garage (*Heated Garage*) with a value of one if the garage is heated and zero otherwise, age of the property in years at the time it sold (*Age*), the elevation of the property (*Elevation*) in feet, and the acreage of the property parcel (*Acres*); ε is the error term which is assumed to be i.i.d. To control for spatial effects, such as differences in school quality and public amenities, a set of indicator variables for the Multiple Listing Service

(MLS) area is included. A_j has a value of one if home i is located in MLS area number j and zero otherwise. To control for temporal effects, such as changes in the economy and housing market, indicator variables for year (Y_k) and quarter (Q_m) of sale are included. Y_k has a value of one if home i was sold in year k and zero otherwise. Q_m has a value of one if home i was sold in quarter m and zero otherwise. r_i is an indicator variable with a value of one if home i completed the Rebate program and zero otherwise. $\beta, \gamma, \delta, \zeta$ and ψ are estimated coefficients. The parameter of interest, ψ, is the average percentage premium estimated for a home that completed the Rebate program.

The square footage, number of bedrooms and bathrooms, garage car capacity, the presence of a heated garage, and acreage of the property parcel are expected to be positively related to the selling price of a home. Elevation is also expected to have a positive relationship to the selling price of a home because during temperature inversions[11], homes in the hills of Fairbanks enjoy warmer temperatures than homes located at lower elevations. Additionally, homes in the hills may escape the ice fog and air quality issues associated with inversion conditions[12]. Age is expected to be negatively related to the selling price of a home because older homes tend to be less energy efficient than newer homes and could potentially require other costly renovations.

[11] A temperature inversion is when the temperature increases, as opposed to falling, with gains in elevation. Temperature inversions typically occur during the winter when cold air pools and remains in low lying areas due to lack of wind to mix the atmosphere, snow cover reflecting sunlight, and limited sunlight hours to heat the surface (Rozel, 2007). Temperature inversions are frequently accompanied by poor air quality because air pollution gets trapped close to the ground.

[12] When temperatures fall below -34° C (-30° F) ice fog can develop because the air is too cold to absorb warm water vapor generated from sources such as car and power plant exhaust. The warm vapor crystalizes in the cold air creating a dense fog.

Two separate models are estimated. First, the hedonic pricing function in Eq. 2.1 is estimated using the full sample of home sales. Next, Eq. 2.1 is estimated using a subset of control homes that are matched to Rebate homes based on their observable attributes using propensity score matching (PSM). It is possible that the homes of those who selected into the Rebate program were more valuable before undergoing the energy efficiency retrofit through the Rebate program. PSM can reduce selection bias by statistically matching the homes of those who selected into the Rebate program with a control group of similar homes based on the observable characteristics of the homes (Rosenbaum and Rubin, 1985). To establish an appropriate control group, a logit model of the likelihood of participation in the Rebate program is estimated using the home attributes and the MLS area indicator variables used in the hedonic model in Eq. 2.1.

$$\pi(x) = \frac{\exp(\alpha + \beta X_i + \sum_{j=1}^{11} \gamma_j A_j)}{1 + \exp(\alpha + \beta X_i + \sum_{j=1}^{11} \gamma_j A_j)} \qquad (2.2)$$

The predicted propensity scores are used to implement an algorithm for one-to-three nearest neighbor matching. Each treatment property is matched to three control properties based on the estimated propensity score. A control property can be matched to more than one treatment property based on its propensity score. PSM makes the treatment group and the control group more comparable by controlling for home attributes that may affect whether a homeowner selected into the Rebate program.

2.5 Data

Data on resales of existing single-family, detached residential properties in Fairbanks from 2008 through 2015 were obtained from the Alaska Multiple Listing Service. The data include the transaction price along with the hedonic characteristics of the property such as its square footage, number of bedrooms, number of bathrooms, age, the car capacity of garage, whether the garage is heated, and acreage of property parcel. Data on the elevation of properties was obtained from the United States Geological Survey (United States Geological Survey, 2016). Any home that did not have a selling price was removed from the dataset. Properties without plumbing, known as dry cabins, were also removed from the sample because they belong to a separate market segment than homes with plumbing. Additionally, no dry cabins in the sample participated in the Rebate program. If a home did not have at least one bathroom and one bathroom, it was assumed to be a dry cabin and was removed from the sample.

Data on properties that participated in the Rebate program were obtained from the Cold Climate Housing Research Center which manages the Alaska Retrofit Information System database on behalf of the AHFC. While the data do not include the specific energy efficiency measures pursued by participants, the information does include the physical addresses of the properties and the date of the post-improvement energy audit for homes that received the rebate. The addresses of program participants were matched to those in the MLS dataset, and properties that sold after they participated in the Rebate program were identified. Homes that completed the Weatherization program were removed from the data set because they underwent an energy efficiency retrofit and therefore are not a suitable control group. Homes that completed an as-is audit but did not complete the program were also removed from the sample because it is possible that the owners of these homes began retrofitting their homes but did not complete renovations in the required 18-month time period. After cleaning the dataset, 6,094 property sales remained for analysis of which 309 (5%) were sold after participating in the Rebate program.

Table 2.4 displays the summary statistics of the transactions in the sample. The mean transaction price of a single-family house is $231,668. The mean size of a home is 1,835 square feet with two bathrooms and three bedrooms. The average age of a home is 24 years. Table 2.5 displays summary statistics broken out by Rebate program participation. Both Rebate and non-Rebate homes have roughly equal numbers of bathrooms, elevations, and acreage. However, homes that participated in the Rebate program are more likely to have larger garages that are heated than homes that did not participate. Rebate homes are, on average, nine years older and over 170 square feet larger than non-Rebate homes. Older homes tend to be less energy efficient than newer homes, and larger homes cost more to heat than a smaller homes with comparable energy efficiency because heating additional square footage requires additional energy consumption. The owners of older and larger homes may have been attracted to the Rebate program because they stood to gain greater potential costs savings from energy efficiency improvements than the owners of newer, smaller homes.

Table 2.6 shows the distribution of housing transactions by year sold, MLS area, participation in the Rebate program, Rebate participant housing transactions by year sold, and decade of construction. The distribution of the pre- and post-retrofit energy efficiencies of all Rebate participant properties is shown in Figure 2.2. In the sample, the average energy efficiency rating of a home that participated in the Rebate program is 3.2 Stars pre-retrofit and 4.2 Stars post-retrofit.

Table 2.7 presents the summary statistics for the matched dataset and Table 2.8 presents the summary statistics broken out by Rebate program participation for the matched sample. In the matched sample, there are 1,100 observations, and the mean values for each of the home characteristics are statistically equivalent for the Rebate and non-Rebate groups.

2.6 Results

Table 2.9 displays the results from the regression analysis using the full sample along with heteroscedasticity robust standard errors. Coefficients for the spatial and temporal fixed effects are not presented. In Model 1, estimated using the full transaction dataset, the estimated coefficients have the expected signs. The Rebate price premium is statistically significant at the one percent level and indicates that a home that completed the Rebate program sells for a 15.5% premium over comparable single-family residences that did not participate in the program in Fairbanks.[13] This shows that home buyers in Fairbanks are willing to pay a premium for energy efficient properties. The effect of participating in the Rebate program on the transaction price of a home amounts to $35,909 at the mean Fairbanks property selling price of $231,668.

The coefficients on house characteristics all have the expected sign and are statistically significant. The model has an approximate R^2 of .60 indicating that 60% of the variation in housing prices in Fairbanks is explained by the model. The results indicate that each additional bedroom adds 2% ($4,633) to a home's selling price while an additional bathroom adds 3% ($6,950). Adding an additional 100 square feet to the area of a home increases the home's transaction price by 2% ($4,633). A home with a heated garage sells for a premium of approximately 23% ($53,284). Because engines can be damaged by repeated starts in cold weather, car owners in Fairbanks generally winterize[14] their cars and must plug them into an electrical socket for several hours before starting the car. If a homeowner has a heated garage, they do not need to plug in their car while at home and can save money on electricity.

[13] Because of the log-level functional form of the model, the transformation of $100 * \beta$ is used for the interpretation of the coefficients for continuous variables (Wooldridge, 2006). However, the transformation of $100 * [\exp(\beta) - 1]$ is used for the interpretation of the estimated coefficients of indicator variables (Halvorsen and Palmquist, 1980).

[14] To weatherize an automobile engine block, oil pan, and battery pad heaters are installed and attached to an electric cord that comes out the front of the car.

Additionally, there is a convenience and comfort factor associated with a heated garage. Most heated garages are attached to the home which prevents a homeowner from having to go outside to get into their car, and the car's interior is warmer from being parked in the heated garage than it would be if it had been parked outside on a cold day. A 100 foot increase in elevation adds 1% ($2,317) to a property's transaction price. Each additional decade of age reduces a property's sale price by 9% ($20,850).

To assess the robustness of the results, several variations of the model are specified. These specifications include models that do not control for spatial and/or temporal fixed effects. Column two of Table 2.9 reports the results of Model 2 which controls for spatial fixed effects but does not control for temporal fixed effects. In this model, the premium associated with participating in the Rebate program is approximately 13% ($30,117). Column three reports the results of Model 3 which controls for temporal fixed effects but does not control for spatial fixed effects. In this model, the premium associated with participating in the Rebate program is approximately 16% ($37,067). Column four reports the results of Model 4 which controls for neither temporal nor spatial fixed effects. In this model, the premium associated with participating in the Rebate program is approximately 14% ($34, 750). Parameter estimates are relatively stable across all four model specifications. Omitting the spatial and temporal fixed effects can result in bias parameter estimates.

Table 2.10 presents estimates from the PSM sample regressions with heteroscedasticity robust standard errors. Model 1 which controls for both spatial and temporal fixed effects explains 60% of the variation in home sales prices in Fairbanks. In this model, Rebate participation is associated with an approximate 15.1% price premium and is statistically significant at the 1% level. The effect of participating in the Rebate program on the selling price of a home amounts to $35,035 at the mean Fairbanks property selling price of $232,020 in the PSM sample.

The parameters estimated with the PSM sample are similar to the parameter estimates in Model 1 in Table 2.9 estimated with the whole sample. However, with the PSM sample, the parameter estimate for elevation is no longer statistically significant in two of the four models. Another notable difference is that the price premium associated with a heated garage is substantially smaller when the model is estimated with the PSM sample, roughly 18% ($41,764), as opposed to 23% ($53,284) when the full sample is used. One explanation for this is that in the full sample, Rebate participants are nearly 10% more likely than non-Rebate participants to have a heated garage, whereas in the PSM sample, Rebate participants and non-Rebate participants are equally likely to have a heated garage. Columns two, three, and four of Table 2.10 present the results of models estimated without temporal and/or spatial fixed effects. As mentioned previously, the omission of these fixed effects can bias parameter estimates.

In Fairbanks, the price premium associated with energy efficient properties is much higher than the price premium found in other studies in other cold weather regions (Cerin et al., 2014; Harjunen and Liski, 2014; Mandell and Wilhelmsson, 2011; Fuerst et al., 2016). However, the previous studies focus on property markets in cosmopolitan areas; Fairbanks is rural in comparison. It may be the case that housing prices in urban Scandinavian markets are driven more by factors such as the proximity to work and distance to downtown area than by energy efficiency. Additionally, while the cities in previous studies are located in cold climate regions, none are located in regions with a subarctic climate. Energy saving potential for energy efficient properties is greater in regions with a subarctic climate than in regions with an oceanic or continental climate because of the greater number of heating degree days in regions with a subarctic climate (Considine, 2000; Fuerst et al., 2016).

2.7 Conclusion and Policy Implications

Between 2008 and 2015, 3,069 homeowners in Fairbanks participated in the Rebate program, and the average rebate for Fairbanks homeowners was $6,378. Although the Rebate program has been suspended, the impacts of the Rebate program remain. The analysis indicates that residential energy efficiency improvements made by Rebate program participants were capitalized into the selling prices of the homes. Therefore, program participants benefit from the program in two ways. First, they benefit from reduced home energy expenditures resulting from the energy efficiency improvements made to their homes. Second, program participants who sold their homes after participating in the program benefited from a significant price premium associated with the improved energy efficiency of their home. However, it should be noted that it does not appear that homeowners participated in the program solely as a means of increasing the resale value of their homes since only 309 of the 3,609 (8.5%) Rebate participants in Fairbanks sold their homes after completing the program.

Because both energy consumption and prices are relatively high in Fairbanks, even modest improvements in energy efficiency can significantly reduce annual residential energy expenditures. The AHFC estimates that on average Rebate program participants reduced their home energy costs by 30% (Information Insights, 2009). As mentioned previously, the average annual energy costs for homes in Fairbanks are estimated to be $8,110 (AHFC, 2014). Thus, on average, a Rebate participant in Fairbanks could expect to reduce their annual energy costs by over $2,430. The average program participant invested $11, 681 in improvements, and received an average rebate of $6,378 (Ord, 2015; Waterman, 2016). After deducting the $500 reimbursement for the as-is and post-improvement energy audits, the average homeowner's out-of-pocket investment was approximately $4,800 (Ord, 2015). Therefore, the average program participant in Fairbanks could expect to recoup their private investment in energy savings in less than two years, and the simple payback period for the combined public and private investment is less than five years.

The premium a homebuyer is willing to pay for an energy efficient property is related to their expected energy savings. The results indicate that homes retrofitted through the Rebate program sell for a premium of between 15.1% and 15.5% which for the average priced home in Fairbanks equates to a premium of $35,035 for the PSM sample and $35,909 for the full sample. Assuming a Rebate participant house in Fairbanks saves its owner the program average of $2,430 per year, a homebuyer would have to occupy it nearly 15 years to recoup the price premium. The large price premium may reflect homebuyer expectations that energy prices will increase over their anticipated tenure in the home which would reduce the length payback period.

Homes that have undergone energy efficiency retrofits through the Rebate program sell for a substantial premium over similar homes that did not participate in the program. Although these results are specific to Rebate homes, they can be generalized to single-family residences across Fairbanks that have undergone energy efficiency retrofits. These results show that even without the Rebate program, home energy efficiency improvements are a worthwhile investment for homeowners in Fairbanks because they are capitalized into the value of the home and homebuyers in Fairbanks are willing to pay a premium for an energy efficient property. The average Rebate participant spent $11,681 pre-rebate on energy efficiency improvements and received a transaction price premium of over $35,000 meaning that the premium received for energy efficiency measures exceed their installed cost.

Future research on energy efficiency in Fairbanks could focus on the energy efficiency ratings of properties to determine how energy efficiency ratings affect the transaction prices of residential properties. Studies could also focus on the cost savings resulting from different energy efficiency measures to determine if the energy savings are capitalized into the value of the homes. Future research could also examine the effect the of the Rebate program on home prices in other relatively large Alaska property markets, such as the Municipality of Anchorage, the Matanuska-Susitna Borough, or the City and Borough of Juneau to gain a better understanding of how Alaskans value energy efficiency.

2.8 References

ACRC (Alaska Climate Research Center), 2016. Fairbanks AP. http://climate.gi.alaska.edu/Climate/fairbanks (accessed 12.06.16).

Alaska Division of Community and Regional Affairs, 2008. Current community conditions: Fuel prices across Alaska, June 2008 update. https://www.commerce.alaska.gov/web/Portals/4/pub/BulkFuelReportJune2008Update.pdf (accessed 28.06.16).

Alaska Energy Authority, 2012. Alaska Energy Authority end use study: 2012. http://www.akenergyauthority.org/Content/Efficiency/EndUse/Documents/AlaskaEndUseStudy2012.pdf (accessed 22.07.16).

AHFC (Alaska Housing Finance Corporation), 2013. Home energy rebate program guidelines. https://www.ahfc.us/files/1913/7401/5545/HER_program_guidelines.pdf (accessed 08.13.16).

AHFC (Alaska Housing Finance Corporation), 2014. Alaska housing assessment. https://www.ahfc.us/efficiency/research-information-center/housing-assessment/ (accessed 03.04.16).

Alaska Journal of Commerce, 2008. Weatherization, home energy funds becoming available. http://www.alaskajournal.com/community/2008-05-25/weatherization-home-energy-funds-becoming-available#.V-QSM6L-R4N (accessed 18.09.16).

Anderson, J., 2015. Committee minutes. Alaska state legislature house special committee on energy. http://www.legis.state.ak.us/basis/get_single_minute.asp?session=29&house=H&comm=ENE&date=20150127&time=1019 (accessed 08.10.16).

Baltensperger, A., 2016. Map of Alaska with the FNSB shaded yellow. ArcGIS.

Boardman, B., 2010. Fixing fuel poverty: Challenges and solutions. Earthscan, New York.

Bond, S.A., Devine, A., 2016. Certification matters: Is green talk cheap talk? Journal of Real Estate Finance and Economics 52, 117-140.

Buildings Performance Institute Europe, 2014. Alleviating fuel poverty in the EU: Investing in home renovation, a sustainable and inclusive solution. http://bpie.eu/wp-content/uploads/2015/10/Alleviating-fuel-poverty.pdf (accessed 09.10.16).

Brehmer, E., 2016. Budget deficit hits state energy programs, rebates cut. Alaska Journal of Commerce. http://www.alaskajournal.com/2016-03-02/budget-deficit-hits-state-energy-programs-rebates-cut#.V-czn6L-R4O (accessed 01.09.16).

Bruegge, C., Carrión-Flores, C., Pope, J.C., 2016. Does the housing market value energy efficient homes? Evidence from the energy star program. Regional Science and Urban Economics 57, 63-76.

Cerin, P., Hassel, L.G., Semenova, N., 2014. Energy performance and housing prices. Sustainable Development 22, 404-419.

Chegut, A., Eichholtz, P., Holtermans, R., 2016. Energy efficiency and economic value in affordable housing. Energy Policy 97, 39-49.

Considine, T.J., 2000. The impacts of weather variations on energy demand and carbon emissions. Resource and Energy Economics 22 (4), 295-314.

de Ayala, A., Galarraga, I., Spadaro, J.V., 2016. The price of energy efficiency in the Spanish housing market. Energy Policy 94, 16-24.

Dinan, T.M., Miranowski, J.A., 1989. Estimating the implicit price of energy efficiency improvements in the residential housing market: A hedonic approach. Journal of Urban Economics 25, 52-67.

DOE (Department of Energy), 2017. Building energy codes program: Status of state energy code adoption. https://www.energycodes.gov/status-state-energy-code-adoption (accessed 01.03.17).

EIA (Energy Information Administration), 2013. Heating and cooling no longer majority of U.S. home energy use. http://www.eia.gov/todayinenergy/detail.cfm?id=10271&src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-b1 (accessed 27.07.16).

EIA (Energy Information Administration), 2015. Energy units and calculators explained: Degree-days. http://www.eia.gov/energyexplained/index.cfm?page=about_degree_days (accessed 18.07.16).

EIA (Energy Information Administration), 2016a. U.S. regional weather data. https://www.eia.gov/forecasts/steo/tables/pdf/9ctab.pdf (accessed 19.06.16).

EIA (Energy Information Administration), 2016b. Average price of electricity to ultimate customers by end-use sector, Electric Power Monthly. https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a (accessed 23.11.16).

Eichholtz, P., Kok, N., Quigley, J.M., 2010. Doing well by doing good? Green office buildings. American Economic Review 100 (5), 2492-2509.

Energy Star, 2016. History of Energy Star guidelines for new homes. https://www.energystar.gov/index.cfm?c=new_homes.nh_history (accessed 15.09.16).

EUR-Lex, 2007. Energy efficiency: Energy performance of buildings. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al27042 (accessed 24.07.16).

Fuerst, F., McCallister, P., 2011. The impact of energy performance certificates on the rental and capital values of commercial property assets. Energy Policy 39 (10), 6608-6614.

Fuerst, F., Oikarinen, E., Harjunen, O., 2016. Green clientele effects in the Helsinki metropolitan area housing market, City of Helsinki Urban Facts Working Papers 2016:3.

GVEA (Golden Valley Electric Authority), 2016. Rates. http://www.gvea.com/rates/rates (accessed 21.11.16).

Goldsmith, S., Pathan, S., Wiltse, N., 2012. Snapshot: the home energy rebate program. Institute of Social and Economic Research, University of Alaska Anchorage. http://cchrc.org/docs/snapshots/HERP_snapshot.pdf (accessed 13.09.16).

Halvorsen, R., Palmquist, R., 1980. The interpretation of dummy variables in semilogarithmic equations. The American Economic Review 70 (3), 474-475.

Harjunen, O., Liski, M. 2014. Not so myopic consumers – evidence of capitalisation of energy technologies in a housing market. CESifo Working Paper Series, No. 4989.

Hobson, M.K., 2016. Alaska: Economist explains bleak economic realities of oil crash. E&E Publishing. http://www.eenews.net/stories/1060036804 (accessed 08.09.16).

Indiana University Bloomington, 2016. Green building background. http://sustain.indiana.edu/programs/green-building/background.php (accessed 12.09.16).

Information Insights, 2009. Alaska housing assessment: Part I and II. http://www.cchrc.org/docs/reports/TR_2009_02_2009_AK_Housing_Assessment_Final.pdf (accessed 01.09.16).

Kontonasiou, E., Mariottini, F., Atanasiu, B., 2015. Tackling fuel poverty with building renovation. ECEE Summer Study Proceedings. http://bpie.eu/wp-content/uploads/2015/11/Tackling-fuel-poverty-with-building-renovation.pdf (accessed 11.10.16).

Laquatra, J., Dacquisto, D.J., Emrath, P., Laitner, J.A., 2002. Housing market capitalization of energy efficiency revisited. ACEEE Summer Study of Energy Efficiency in Buildings, Teaming for Efficiency, Proceedings 8.

Mandell, S., Wilhelmsson, M., 2011. Willingness to pay for sustainable housing. Journal of Housing Research 20 (1), 35-51.

Merriam-Webster, 2017. Definition of district heating. https://www.merriam-webster.com/dictionary/district%20heating (accessed 13.03.17).

Meyer, J., Pride, D., O'Toole, J., Craven, C., Spenser, V., 2011. Ground-source heat pumps in cold climates. Alaska Center for Energy and Power. http://www.uaf.edu/files/acep/Ground-Source-Heat-Pumps-in-Cold-Climates.pdf (accessed 13.06 2016).

Nevin, R., Watson, G., 1998. Evidence of rational market valuations for home energy efficiency. The Appraisal Journal 66, 401-408.

Ord, J., 2015, January 27. Committee minutes. Alaska State Legislature House Special Committee on Energy. http://www.legis.state.ak.us/basis/get_single_minute.asp?session=29&house=H&comm=ENE&date=20150127&time=1019 (accessed 23.09.16).

Reichardt, A., Fuerst, F., Rottke, N.B., Zietz, J., 2012. Sustainable building certification and the rent premium: a panel data approach. Journal of Real Estate Research 34 (1), 99-126.

Roberts, S., 2008. Energy, equity and the future of the fuel poor. Energy Policy 36 (12), 4471-4474.

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy 82 (1), 34-55.

Rosenbaum, P.R., Ruben, D.B., 1985. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. American Statistics 39, 33-38.

Rozel. N., 2007. Alaska temperature inversions go to extremes. Alaska Report. http://www.alaskareport.com/science10059.htm (accessed 26.09.16).

Saylor, B., Haley, S., Szymoniak, N., 2008. Estimated household costs for home energy use, May 2008. Institute of Social and Economic Research, University of Alaska Anchorage. http://www.iser.uaa.alaska.edu/Publications/webnote/LLFuelcostupdatefinal.pdf (accessed 21.09.16).

Sierra Research, 2015. Analysis of Fairbanks 2013-2015 home heating surveys. https://dec.alaska.gov/air/doc/Fbks_2013-15_HHSurvey.pdf (accessed 28.09.16).

Sivak, M., 2013. Air conditioning versus heating: climate control is more energy demanding in Minneapolis than Miami. Environmental Research Letters 8 (1), 1-4.

Tichotsky, J., 2014. Alaska state revenues: overview, history, and forecast Alaska department of revenue forum on Alaska's fiscal future October 4, 2014. http://akcommonground.org/wp-content/uploads/2014/10/Tichotsky-John-Alaska-State-Revenues-for-Oct-4-2014-Fiscal-Future-Forum.pdf (accessed 07.08.16).

United States Geological Survey, The national map: Elevation. http://nationalmap.gov/elevation.html (accessed 19.05.16).

U.S. Census Bureau, 2015. QuickFacts: Fairbanks North Star Borough, Alaska. http://www.census.gov/quickfacts/table/PST045215/02090 (accessed 23.06.16).

U.S. Department of Energy, 2016. Building energy codes program: Alaska. https://www.energycodes.gov/adoption/states/alaska (accessed 14.07.16).

Walls, M., Palmer, K., Gerarden, T., Bak, X., 2016. Is energy efficiency capitalized into home prices? Evidence from three U.S. cities. Resources for the Future, working paper.

Waterman, S., 2016, October 20. Alaska Housing Finance Cooperation State Energy Program Manager, e-mail message to author.

Wiley, J.A., Benefield, J.D., Johnson, K.H., 2010. Green designs and the market for commercial office space. Journal of Real Estate Finance and Economics 41, 228-243.

Wooldridge, J., 2006. Introductory econometrics: A modern approach. Thompson South-Western, Mason OH.

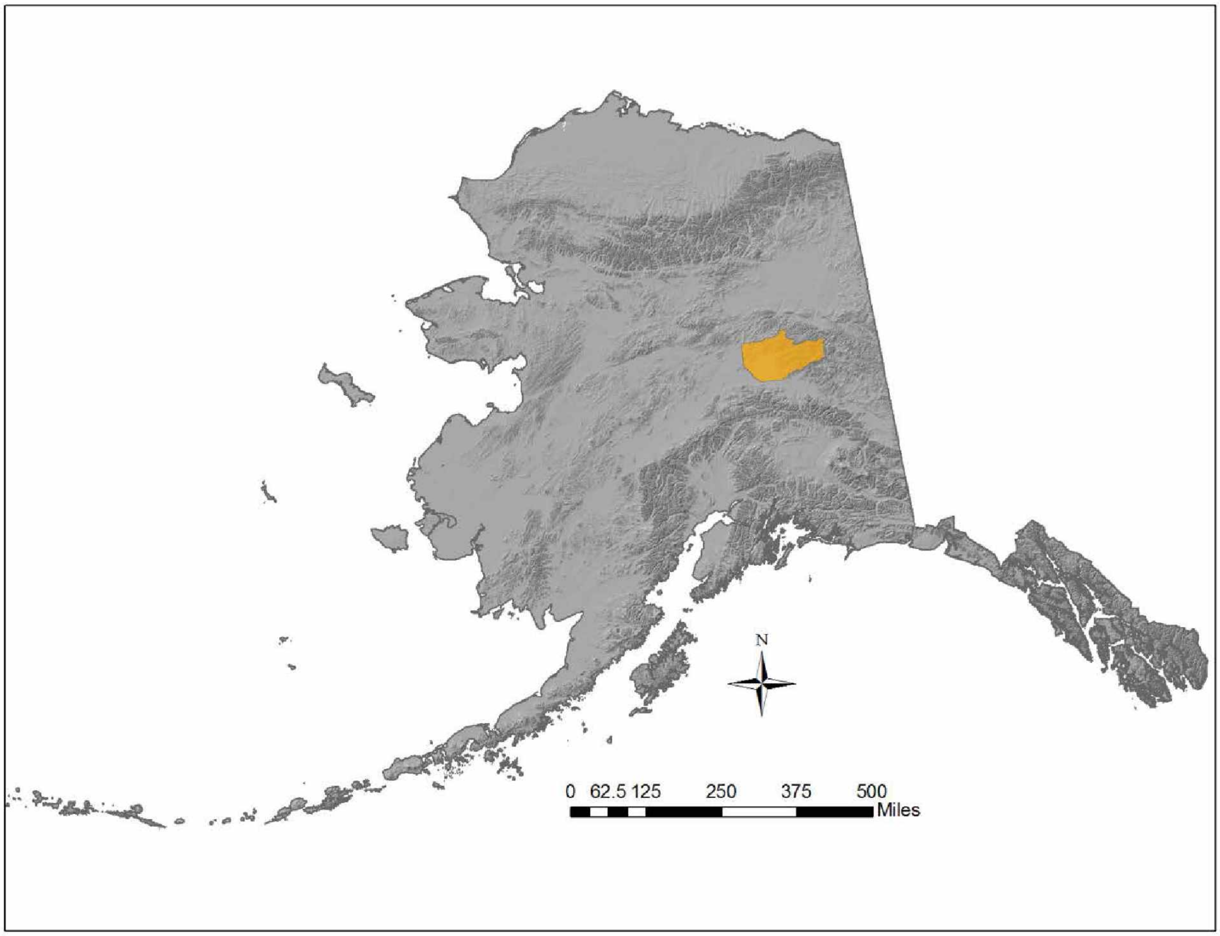

Figure 2.1. Map of Alaska with the FNSB shaded yellow (Baltensperger, 2016)

Table 2.1. State appropriations for residential energy efficiency programs (million USD)

Fiscal Year	Home Energy Rebate	Weatherization
2008	$100	$200
2009	$60	0
2010	0	0
2011	0	0
2012	$37.5	$62.5
2013	$20	30
2014	$20	30
2015	$15	$27.5
Program Total	$252.5	$350

Table 2.2. Point values for energy ratings

Points	Ratings
0-39	1 Star
40-49	1Star +
50-59	2 Star
60-67	2 Star +
68-72	3 Star
73-77	3 Star +
78-82	4 Star
83-88	4 Star +
89-91	5 Star
92-94	5 Star +
95-100+	6 Star

Table 2.3. Maximum possible rebate by steps

Steps	Maximum Possible Rebate
1 Steps	$4,000
2 Steps	$5,500
3 Steps	$7,000
4 Steps	$8,500
5 Steps	$10,000

Table 2.4. Summary statistics (full sample)

Variable	Definition	Mean	Std. Dev.	Min.	Max.
Price	Transaction price of the property	231,668	86,664	15,160	702,025
lnRprice	Natural log of transaction price	12.27	0.45	9.63	13.46
Rebate	Indicator variable for Rebate participation	0.05	0.22	0.00	1.00
Square feet	Square footage of the residence	1,835	712	384	6,200
Bathrooms	Number of bathrooms	2.17	0.81	1.00	7.00
Bedrooms	Number of bedrooms	3.08	0.89	1.00	8.00
Garage Capacity	Number of cars a garage can hold	1.60	1.02	0.00	8.00
Heated Garage	Indicator variable for heated garage	0.75	0.44	0.00	1.00
Age	Age of property at time of sale	24.09	15.99	0.00†	106
Elevation	Elevation of the property in feet	584	224	398	2,166
Acres	Acreage of property	1.53	3.28	0.00	135

† Seven houses in the sample were resold the same year they were built.

Table 2.5. Comparison of Home Energy Rebate participant homes to nonparticipant homes (full sample)

Variable	Definition	Rebate Status	Mean	Std. Dev.	Min.	Max.
Price***	Transaction price of the property	Rebate = 1	250,075	68,261	45,784	58,5694
		Rebate = 0	230,685	87,434	15,160	702,025
lnRprice***	Natural log of transaction price	Rebate = 1	12.39	0.28	10.73	13.28
		Rebate = 0	12.26	0.45	9.63	13.46
Square feet	Square footage of the residence	Rebate = 1	2,000	692	600	5474
		Rebate = 0	1,826	712	384	6200
Bathrooms	Number of bathrooms	Rebate = 1	2.23	0.73	1.00	4.00
		Rebate = 0	2.17	0.82	1.00	7.00
Bedrooms***	Number of bedrooms	Rebate = 1	3.23	0.81	1.00	6.00
		Rebate = 0	3.07	0.89	1.00	8.00
Garage capacity**	Number of cars a garage can hold	Rebate = 1	1.74	0.90	0.00	6.00
		Rebate = 0	1.59	1.03	0.00	8.00
Heated garage***	Indicator variable for heated garage	Rebate = 1	0.83	0.37	0.00	1.00
		Rebate = 0	0.74	0.44	0.00	1.00
Age***	Age of property at sale	Rebate = 1	32.93	11.80	4.00	76.00
		Rebate = 0	23.62	16.05	0.00†	106
Elevation	Elevation of the property in feet	Rebate = 1	591	226	431	1,606
		Rebate = 0	583	223	398	2,166
Acres	Acreage of property	Rebate = 1	1.30	2.08	0.05	26.56
		Rebate = 0	1.54	3.34	0.00	135

† Seven houses in the sample were resold the same year they were built. Difference in group means significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Table 2.6. Distribution of housing transactions

A. Distribution of housing transactions by year		
Year	Frequency	Percentage
2008	674	11%
2009	760	12%
2010	812	13%
2011	716	12%
2012	759	12%
2013	743	12%
2014	797	13%
2015	833	14%
Total	6,094	100%
B. Distribution of housing transactions by MLS area		
MLS Area	Frequency	Percentage
Badger and Rural North Pole	1,979	32%
Chena Hot Springs Road	186	3%
City of North Pole	233	4%
East Fairbanks	345	6%
East Rural Fairbanks	471	8%
North Fairbanks	764	13%
Northwest Rural Fairbanks	334	5%
Rural Fairbanks	594	10%
Salcha	69	1%
South Fairbanks	253	4%
Southwest Rural Fairbanks	474	8%
West Fairbanks	392	6%
Total	6,094	100%
C. Distribution of housing transactions by Home Energy Rebate participation		
Rebate	Frequency	Percentage
0	5,785	95%
1	309	5%
Total	6,094	100%
D. Distribution of Home Energy Rebate participant housing transactions by year		
Year	Frequency	Percentage
2008	2	1%
2009	9	3%
2010	24	8%
2011	44	14%
2012	48	16%
2013	55	18%
2014	63	20%
2015	64	21%
Total	309	100%

Table 2.6 continued

E. Distribution of housing transactions by decade of construction		
Year	Frequency	Percentage
Pre-1950	90	1%
1950-1959	286	5%
1960-1969	322	5%
1970-1979	1,077	18%
1980-1989	1,657	27%
1990-1999	729	12%
2000-2009	1,830	30%
Post-2009	103	2%
Total	6,094	100%

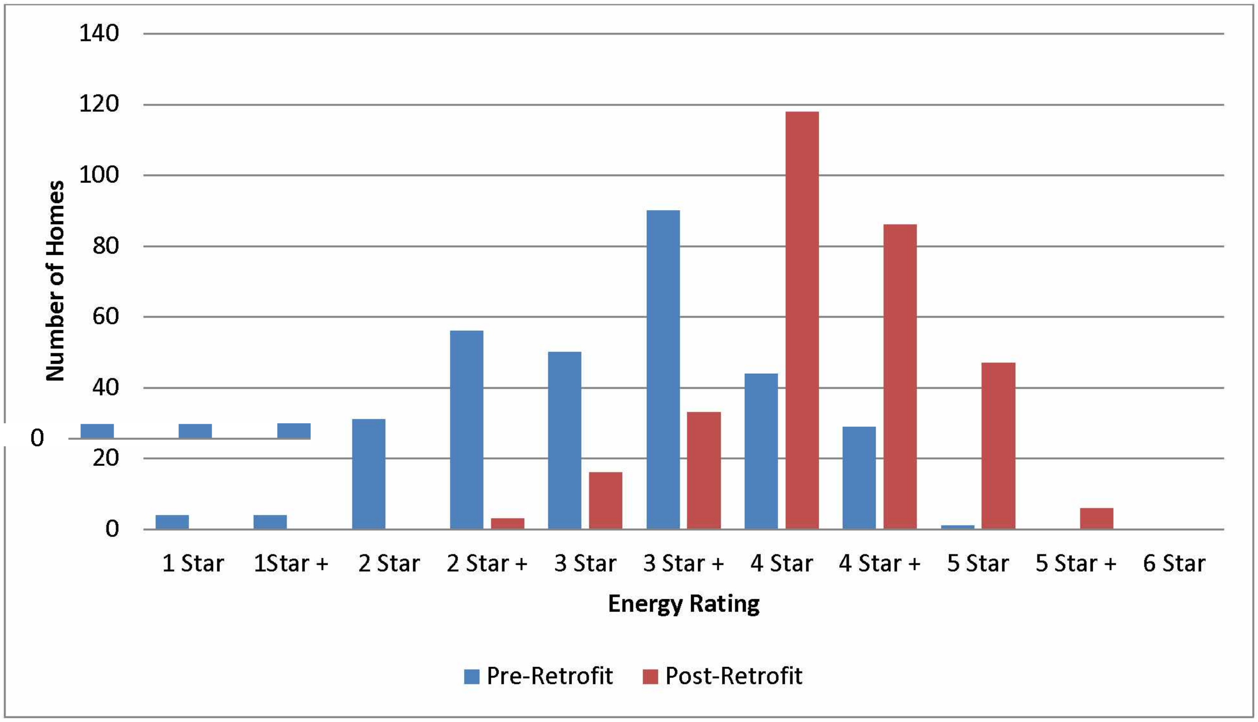

Figure 2.2. Distribution of Rebate participants' pre- and post-retrofit energy ratings

Table 2.7. Summary statistics (PSM sample)

Variable	Definition	Mean	Std. Dev.	Min.	Max.
Price	Transaction price of the property	232,020	83,340	33,500	702,025
lnRprice	Natural log of transaction price	12.28	0.413	10.42	13.46
Rebate	Indicator variable for Rebate participation	0.28	0.450	0.00	1.00
Square feet	Square footage of the residence	1,946	736	416	6,200
Bathrooms	Number of bathrooms	2.18	0.814	1.00	6.00
Bedrooms	Number of bedrooms	3.19	0.908	1.00	8.00
Garage capacity	Number of cars a garage can hold	1.72	0.955	0.00	8.00
Heated garage	Indicator variable for heated garage	0.82	0.381	0.00	1.00
Age	Age of property at time of sale	33.31	14.83	1.00	106
Elevation	Elevation of the property in feet	580	231	428	2,136
Acres	Acreage of property	1.28	2.90	0.00	80

Table 2.8. Comparison of Home Energy Rebate participant homes to nonparticipant homes (PSM sample)

Variable	Definition	Rebate Status	Mean	Std. Dev.	Min.	Max.
Price***	Transaction price of the property	Rebate = 1	250,075	68,261	45,784	585,694
		Rebate = 0	224,968	87,569	33,500	702,025
lnRprice***	Natural log of transaction price	Rebate = 1	12.39	0.28	10.73	13.28
		Rebate = 0	12.24	0.45	10.42	13.46
Square feet	Square footage of the property	Rebate = 1	2,000	692	600	5,474
		Rebate = 0	1,926	752	416	6200
Bathrooms	Number of bathrooms	Rebate = 1	2.23	0.73	1.00	4.00
		Rebate = 0	2.16	0.84	1.00	6.00
Bedrooms	Number of bedrooms	Rebate = 1	3.23	0.81	1.00	6.00
		Rebate = 0	3.17	0.94	1.00	8.00
Garage Capacity	Number of cars a garage can hold	Rebate = 1	1.74	0.90	0.00	6.00
		Rebate = 0	1.71	0.97	0.00	8.00
Heated Garage	Indicator variable for heated garage	Rebate = 1	0.83	0.37	0.00	1.00
		Rebate = 0	0.82	0.39	0.00	1.00
Age	Age of property at sale	Rebate = 1	32.93	11.80	4.00	76.00
		Rebate = 0	33.46	15.86	1.00	106
Elevation	Elevation of the property in feet	Rebate = 1	591	226	431	1,606
		Rebate = 0	576	234	428	2,136
Acres	Acreage of property	Rebate = 1	1.30	2.08	0.05	26.56
		Rebate = 0	1.28	3.16	0.00	80.00

Difference in group means significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Table 2.9. Home Energy Rebate price premium (full sample)

Dependent variable: ln(Sale Price)	Model 1:	Model 2:	Model 3:	Model 4:
Rebate	**0.1440*****	**0.1260*****	**0.1504*****	**0.1321*****
	(0.0121)	**(0.0119)**	**(0.0125)**	**(0.0123)**
Square Feet	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bedrooms	0.0231***	0.0231***	0.0209***	0.0210***
	(0.0065)	(0.0066)	(0.0068)	(0.0068)
Bathrooms	0.0336***	0.0292***	0.0526***	0.0486***
	(0.0075)	(0.0076)	(0.0077)	(0.0078)
Garage Capacity	0.0701***	0.0695***	0.0586***	0.0576***
	(0.0056)	(0.0057)	(0.0055)	(0.0056)
Heated Garage	0.2082***	0.2071***	0.2177***	0.2171***
	(0.0143)	(0.0145)	(0.0147)	(0.0149)
Age	-0.0087***	-0.0091***	-0.0079***	-0.0083***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Elevation	0.0001**	0.0001**	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Acres	0.0027*	0.0024	-0.0006	-0.0010
	(0.0015)	(0.0015)	(0.0017)	(0.0017)
Constant	11.6300***	11.6044***	11.5761***	11.5574***
	(0.0255)	(0.0223)	(0.0248)	(0.0213)
Quarter FE	Yes	No	Yes	No
Year FE	Yes	No	Yes	No
MLS Area Number FE	Yes	Yes	No	No
Observations	6,094	6,094	6,094	6,094
R-squared	0.5969	0.5857	0.5715	0.5596
AIC	1,993	2,139	2,343	2,489

Notes: Heteroscedasticity robust standard errors are reported in parentheses. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Table 2.10. Home Energy Rebate price premium (PSM sample)

Dependent variable: Ln(Sale Price)	Model 1:	Model 2:	Model 3:	Model 4:
Rebate	**0.1407*****	**0.1195*****	**0.1457*****	**0.1231*****
	(0.0163)	**(0.0155)**	**(0.0168)**	**(0.0158)**
Square Feet	0.0002***	0.0002***	0.0002***	0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Bedrooms	0.0266*	0.0276**	0.0287**	0.0303**
	(0.0137)	(0.0134)	(0.0138)	(0.0136)
Bathrooms	0.0440***	0.0363**	0.0507***	0.0423***
	(0.0143)	(0.0147)	(0.0149)	(0.0154)
Garage Capacity	0.0406***	0.0350***	0.0277**	0.0229*
	(0.0125)	(0.0124)	(0.0128)	(0.0126)
Heated Garage	0.1681***	0.1730***	0.1645***	0.1694***
	(0.0342)	(0.0347)	(0.0358)	(0.0362)
Age	-0.0079***	-0.0085***	-0.0071***	-0.0076***
	(0.0007)	(0.0007)	(0.0006)	(0.0006)
Elevation	0.0000	0.0000	0.0001**	0.0001*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Acres	0.0141***	0.0128***	0.0121***	0.0108***
	(0.0045)	(0.0045)	(0.0043)	(0.0041)
Constant	11.7048***	11.6953***	11.7112***	11.6939***
	(0.0613)	(0.0451)	(0.0630)	(0.0451)
Quarter FE	Yes	No	Yes	No
Year FE	Yes	No	Yes	No
MLS Area Number FE	Yes	Yes	No	No
Observations	1,100	1,100	1,100	1,100
R-squared	0.6035	0.5846	0.5721	0.5528
AIC	46	78	108	137

Notes: Heteroscedasticity robust standard errors are reported in parentheses. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Chapter 3

The Value of Energy Efficiency in the Anchorage Residential Property Market[1]

Abstract

The residential sector is a significant source of carbon dioxide emissions. Improving the energy efficiency of the housing stock can reduce carbon emissions and increase property values. This paper examines whether residential energy efficiency improvements are capitalized into home prices in Anchorage, Alaska. Using both a hedonic pricing framework and a difference-in-differences estimator, the impact of participating in a state-funded residential energy efficiency program, the Home Energy Rebate program, on single-family house prices is estimated. The results indicate that participating homes sell for a price premium between 5% and 11% compared to similar properties that did not participate in the program.

3.1 Introduction

In the United States, the residential sector accounts for 21% of total energy consumption and 20% of national CO_2 emissions (Energy Information Administration (EIA), 2016). In the Municipality of Anchorage (Anchorage), Alaska, residential energy consumption is 2.8 times above the national average, largely due to demand for space heating (AHFC, 2014). Space heating accounts for 70% of residential energy consumption in Anchorage compared to the national average of 42% (AHFC, 2014; EIA, 2013). Improving the energy efficiency of the housing stock can reduce residential energy consumption leading to a reduction in residential sector CO_2 emissions (Boardman, 2010).

[1] Pride, D., and Little, J., 2017. The Value of Energy Efficiency in the Anchorage Residential Property Market. Prepared for submission to The Journal of Sustainable Real Estate.

Improving the energy efficiency of the housing stock in Anchorage could significantly reduce CO_2 emissions from the state's residential sector since 40% of the state's population resides in the municipality (U.S. Census Bureau, 2016). Reducing residential CO_2 emissions is important because of the link between anthropogenic CO_2 emissions and climate change (IPCC, 2014). The climate in Alaska is warming at a faster rate than the rest of the nation as a whole (Chapin *et al*., 2014). Over the last six decades, the average annual temperature in Alaska increased by 3°F, while the average winter temperature increased by 6°F (ACRC, 2016).

In addition to reducing CO_2 emissions, reducing residential energy consumption decreases the percentage of household income allocated to energy expenditures (Boardman, 2010). Anchorage households face high energy costs. The average annual energy cost for an Anchorage household is $2,786, which is 30% above the national average (AHFC, 2014). In 2008, Alaska policymakers implemented a new residential energy efficiency program, the Home Energy Rebate (Rebate) program, with the primary policy objective of reducing household energy costs by incentivizing investment in residential energy efficiency improvements (Goldsmith, Pathan, and Wiltse, 2012). Reports examining the outcomes of the Rebate program show the program has been effective in reducing program participants' home energy costs and residential CO_2 emissions (Information Insights, 2009; Dodge, Wiltse, Valentine, 2012; Goldsmith, Pathan, Wiltse, 2012). A previous study investigating the relationship between the Rebate program and home prices in the Fairbanks North Star Borough housing market found that participating homes sell for a 15.1% to 15.5% price premium over similar homes that did not participate in the program (Pride and Little, forthcoming). However, no study has investigated the impact of the Rebate program on the transaction prices of participating homes in Anchorage. Previous studies on residential property markets outside of Alaska show that there is a positive relationship between residential energy efficiency and property prices demonstrating that investments in energy efficiency are often compensated through increased transaction prices. (Laquatra, Dacquisto, Emrath, and Laitner, 2002).

Using a sample of over 26,000 home sales in Anchorage from 2008 through 2015, the effect of participation in the Rebate program on home prices in Anchorage is assessed using a hedonic pricing framework. With a hedonic pricing framework, a home's characteristics are related to its transaction price, controlling for both the time of the sale and geographic location. This method allows for the price premium associated with participating in the Rebate program to be isolated. Assuming a homebuyer does not place a monetary value on reducing their carbon emissions, the price premium a buyer in the residential property market is willing to pay for an energy efficient home should be equal to or less than the present value of the expected energy savings over their anticipated tenure in the home.

This study adds to the literature examining the relationship between energy efficiency and the transaction prices of residential properties. In particular, this study adds to the body of research on the value of residential energy efficiency in areas with cold climates (Cerin, Hassel, and Semenova, 2014; Fuerst, Oikarinen, and Harjunen, 2016; and Mandell and Wilhelmsson, 2011). Homes in cold climates use more energy than homes in more moderate climates (Sivak, 2013.). Therefore, improving the energy efficiency of the housing stock in regions with cold climates could have a larger impact on reducing energy consumption and carbon emissions than improving the energy efficiency of the housing stock in regions with more moderate climates.

The remainder of the paper is structured as follows: the next section reviews the existing literature, followed by a background section on the study area and the Rebate program. Then the methods are discussed, followed by a description of the data used for the analysis. Next the results are presented. The paper concludes with a summary of the study findings and their implications.

3.2 Literature Review

There is a burgeoning body of literature on the effect of energy efficiency on residential property prices. One of the earliest studies relating energy efficiency and residential housing prices is Dinan and Miranowski's (1989) study on whether fuel savings resulting from energy efficiency improvements to 243 homes in Des Moines, Iowa are capitalized into the value of the homes. The authors find that reducing the energy costs used to keep a home at 65°F by \$1, increases a home's expected selling price by \$11.63. Many subsequent hedonic studies based on residential property markets in the United States focus on the price premiums associated with green certification programs such as the Energy Star and the Leadership in Energy and Environmental Design (LEED) programs (Bloom, Nobe, and Nobe, 2011; Bruegge, Carrion-Flores, and Pope, 2016; Bond and Devine, 2016, Kahn and Kok, 2014; Walls, Palmer, Gerarden, and Bak, 2016).

The Energy Star certification program for newly constructed residential homes was created in 1995 by the United States Environmental Protection Agency (Energy Star, 2016a). Guidelines for Energy Star certification have been updated over the years. Since 2012, a new home must use 30% less energy than a typical newly constructed home to receive the Energy Star label. Estimates of the incremental cost to build an Energy Star certified home in regions that have adopted the 2009 International Energy Conservation Code show that depending on the climate zone in which the home is located, the additional cost associated with gaining Energy

Star certification ranges from $1,463 to $2,155 (Energy Star, 2016b). However, the annual energy savings of the Energy Star certified homes range from 14% to 27% and, the simple payback period of the added capital cost of certification ranges from two to five years (Energy Star, 2016b).

Bloom, Nobe, and Nobe (2011) study the impact of the Energy Star certification on home prices in Fort Collins, Colorado. Using a sample of 300 homes sold from 1999 to 2005, the authors find that Energy Star certified homes sell for a price premium of $8.66 per square-foot compared to non-certified homes in the area. Bruegge, Carrion-Flores, and Pope (2016) use a hedonic pricing framework and a repeat sales approach to examine the impact of the Energy Star certification on housing prices in Gainesville, Florida between 1997 and 2009. The results show that Energy Star certified homes sell for a price premium between 1.2% and 4.9% over similar non-certified homes. However, this price premium declines over subsequent sales.

The LEED program was created by the U.S. Green Building Council in 1998 and offers certification for properties that meet standards for the green design, construction, operation, and maintenance of buildings (Indiana University Bloomington, 2016). A study examining the additional construction cost required to build to LEED standards found an average construction cost premium of 2% but suggests this cost premium is recouped through reduced operating costs (Kats et al., 2003). Other studies find no significant difference between average costs of LEED certified versus non-LEED certified buildings (Matthiessen and Morris, 2004; Matthiessen and Morris, 2007). Bond and Devine (2016) examine premiums associated with LEED certified and other green multi-family residential properties across the United States. The authors find that LEED properties rent for a premium between 8.9% and 9.1%. However, properties that are marketed as green but do not have an official green certification rent for a smaller premium of 4.74%.

There are several hedonic studies on property markets within the United States that investigate the residential property price premium associated with multiple green certification programs. Kahn and Kok (2014) document the sale price premium associated with single-family dwellings with Energy Star, LEED, or California's local GreenPoint Rated certifications. Using a sample of over 1.6 million home sales from 2007 through 2012, the authors find that California homes with a green certification sell for a price premium of approximately 5%. When the sample is restricted to the Metropolitan Statistical Areas of Los Angeles, San Diego, and San Francisco and the green certifications are disaggregated, only the premium associated with the Energy Star certification (4.7%) remains statistically significant. Walls, Palmer, Gerarden, and Bak (2016) investigate the price premium associated with the national Energy Star program as well as local green certification programs in Austin, Texas, the Research Triangle in North Carolina, and Portland, Oregon. Using hedonic regression analysis on unmatched and propensity score matched (PSM) samples for each metropolitan area, the authors find that the Energy Star certification is statistically significant across the study areas with the full sample. However, when the PSM sample is used, the Energy Star certification is no longer associated with a statistically significant price premium in Austin, Texas. Using a PSM sample, Energy Star certification is associated with a 2% price premium in both the Research Triangle and Portland markets. The local green certification program is associated with a 7% to 8% price premium in Austin and a 3% price premium in Portland. The local green certifications have more stringent requirements than the national Energy Star program.

In addition to hedonic analysis, difference-in-differences (DiD) estimators have also been used to assess the impact of energy efficiency on property prices. The DiD method is popular in policy analysis for estimating the effects of policies that do not affect the whole population at the same time or in the same way (Lechner, 2010). Reichard, Fuerst, Rottke, and Zietz (2012) use both a DiD and fixed-effects model approach on a large panel dataset of commercial office buildings in the United States from 2000 through 2010 to assess the effect of obtaining sustainable building certification on rental prices. The results of the DiD estimator analysis indicate that buildings that received Energy Star certification rent for an average price premium of between 3.3% to 6.1% from 2004 through 2007 depending on the year of certification. The authors also find that Energy Star certification increases the occupancy rates of buildings by between 2.8% and 3.4% depending on the year of certification. The authors estimate DiD models for LEED certification but do not find it has a significant impact on rent prices or occupancy rates. The results of the fixed effects models indicate that Energy Star and LEED certification have statistically significant average rent premiums of 2.5% and 2.9%, respectively, over the study period. Another relevant study, although not specifically about energy efficiency, examines the impact of residential photovoltaic (PV) energy systems on home sale prices in California from 2000 through 2009 using both a hedonic framework and a DiD estimator (Hoen, Wiser, Cappers, and Thayer, 2011). The results of the hedonic analysis indicate that the installation of PV increases the value of homes by approximately \$3.90 to \$6.40 per installed watt of PV which adds a home sale price premium of approximately \$17,000 for the average sized PV system (3,100 watt) in the study. The results from the DiD analysis for existing homes indicate that homes with solar installations that are installed between the first and second sales of the property sell for a price premium of 5% to 6% which equates to a premium of $6.00 to $6.30 per installed watt.

3.3. Background

3.3.1 Study Area

Anchorage is Alaska's largest city with a population of approximately 300,000 residents (U.S. Census Bureau, 2015). The city has a land area of 1,705 square miles and is located in the south-central region of the state. See Figure 3.1. Anchorage has a subarctic climate with a maritime influence, and experiences cold winters and mild, wet summers. The average annual temperature is 3°C (37°F); average daily high temperatures range from -5°C (23°F) in January to 18°C (65°F) in July (ACRC, 2016). Anchorage has 10,570 heating degree days[2] (HDD) per year, and the average Anchorage household consumes 171.2 million British thermal units[3] (MMBtu) per year for space heating (Information Insights, 2009). By comparison, the region of New England has 6,752 HDD per year and the average household consumes 85.4 MMBtu annually for space heating (Information Insights, 2009). Anchorage residents have access to natural gas due to the city's close proximity to the Cook Inlet natural gas fields. Natural gas is used for over ninety percent of residential space heating in Anchorage (AHFC, 2014).

The amount of energy a home requires for residential space heating depends on the size and energy efficiency of the home. The average size of a home in Anchorage is 1,888 square feet (AHFC, 2014). More than 80% of the Anchorage housing stock is more than 20 years old (Information Insights, 2009). Older homes are typically less energy efficient than newer homes.

[2] Heating degree days are the annual sum of the difference between the average outdoor air temperature over a 24-hour period and a base temperature (typically 65°F). (EIA, 2015).
[3] A British thermal unit (Btu) is the amount of work required to raise a pound of water one degree Fahrenheit.

In Anchorage, homes built during and after the 1990s are far more energy efficient than homes built before the 1990s. The average energy use for Anchorage homes built in the 1980s is 145,000 Btu per square foot compared to 109,000 Btu per square foot for homes built during the 1990s, a 25% decrease (AHFC, 2014). This reduction is likely due in part to the implementation of the state's voluntary energy efficiency certification program, the Building Energy Efficiency Standard (BEES) enacted by the state legislature in 1992 (U.S. Department of Energy, 2016). Although BEES is not a mandatory standard, any new home receiving AHFC financing must be compliant with the version of BEES in effect at the time of the home's construction.

3.3.2 Home Energy Rebate Program

Alaska's economy is closely linked to oil price cycles. Alaska does not have a state income tax. Instead, the state receives the majority of its general revenue from taxes on the petroleum industry and oil and gas royalties (Tichotsky, 2014). When oil prices are high, the state has abundant revenue to fund the state budget. However, high oil prices place a burden on households that rely on petroleum-based products for their home energy needs. High oil prices are especially burdensome on households in rural communities throughout Alaska that do not have access to natural gas (Saylor, Haley, and Szymoniak, 2008). Energy prices tend to be higher in rural areas than in Alaska's urban centers due to difficult fuel delivery logistics among other factors (Wilson et al., 2008). In an effort to alleviate the burden of high home energy costs, legislation establishing the Rebate program was passed in 2008 (Goldsmith, Pathan, Wiltse, 2012).

The Rebate program was administered by the Alaska Housing Finance Corporation[4] (AHFC) and operated from May of 2008 through March 2016 when the program was suspended due to budgetary shortfalls brought about by reduced state revenue resulting from low oil prices (Brehmer, 2016). Through the Rebate program, homeowners could receive a rebate up to $10,000 for making preapproved energy efficiency improvements to their primary residence (AHFC, 2013). Unlike the federally- and state-funded Weatherization program aimed at lower-income households, there were no income qualifications for the Rebate program.

To participate in the program, a homeowner was required to have an initial as-is energy efficiency audit conducted on their home to assess its energy efficiency before any energy efficiency improvements were made. During the as-is audit, an independent energy auditor assigned the home an energy efficiency rating using the state's AKWarm energy modeling software and generated a report that recommended specific energy efficiency improvements along with the estimated total costs and savings associated with each improvement listed in the report. Only the energy efficiency improvements recommended in the report were eligible for reimbursement through the program. However, the homeowner was able to choose which of the recommended improvements to make to their home.

The homeowner had 18 months from the date of as-is energy audit to make recommended improvements and have a post-improvement energy efficiency audit conducted on their home. Program participants paid for the improvements upfront and then received a rebate check after submitting the appropriate paperwork which included the post-improvement rating certificate stating the home's post-improvement energy rating as well as receipts for material, labor, and the

[4] The Alaska Housing Finance Corporation is a public corporation that provides affordable loans for housing and administers public and senior housing programs as well as energy efficiency and weatherization programs.

post-improvement energy audit. The amount of the rebate was based on the increase in the energy efficiency of the property as measured by the increase in energy rating points and star steps between the as-is and post-improvement energy ratings and eligible receipts for contracted labor and materials. Program participants could apply for reimbursement up to $325 for the as-is energy audit and up to $175 for the post-improvement audit. Table 3.1 displays the point values for energy star ratings. It should be noted that the AHFC's energy rating scale is not related to the Environmental Protection Agency's Energy Star certification. A home's energy rating could range from 1 Star to 6 Stars. Moving up the energy efficiency rating scale from a star rating to the next higher star is a step increase. See Table 3.2 for the maximum possible rebate amounts for step increases. Once a home completed the Rebate program, the property was not eligible to participate in program again even if it changed owners.

The Alaska State Legislature appropriated over $250 million for the Rebate program from fiscal year 2008 through fiscal year 2015, and nearly 25,000 homeowners across the state participated in the Rebate program (Brehmer, 2016). The program was popular in Anchorage where approximately 14% (14,690) of occupied housing units completed the program (AHFC, 2014; Waterman, 2016). It is estimated that program participants reduced their annual energy costs by 30% and their residential CO_2 emissions by 35% (Information Insights, 2009). The average rebate received by program participants in the Anchorage area totaled $7,422 (Waterman, 2016).

3.4 Methods

The hedonic pricing framework is well-established in the literature on residential energy efficiency (Laquatra, Dacquisto, Emrath, and Laitner, 2002). Using the hedonic pricing framework, as proposed by Rosen (1974), the transaction price of the home is deconstructed into its constituent characteristics allowing one to determine the contribution of the individual characteristics to the home's transaction price.

3.4.1 Hedonic Regression Model

A semi-log model is estimated using pooled Ordinary Least Squares, relating the transaction price of the home to its physical characteristics, geographic location, time of sale, and participation in the Rebate program.

$$Ln(price_i) = \alpha + \beta X_i + \sum_{j=1}^{12} \gamma_j A_j + \sum_{k=1}^{31} \delta_k Q_k + \psi r_i + \varepsilon_i \quad (3.1)$$

In Eq. 3.1 the dependent variable is the natural log of the selling price of home *i* in 2015 dollars; α is a constant term; X_i is a vector of hedonic characteristics for home *i* including the square footage (*Square feet*) of the residence in hundreds of square feet, number of bedrooms (*Bedrooms*), number of bathrooms (*Bathrooms*), number of cars a garage can hold (*Garage capacity*), an indicator variable for a condominium (*Condo*) with a value of one if the property is a condominium and zero otherwise; the age of the home at the time of sale (*Age*) in years, and the acreage of the property parcel (*Acres*); and ε_i is a random disturbance term. A set of indicator variables indicating the Multiple Listing Service (MLS) area number are included to control for spatial effects such as differences in the availability of public amenities and the varying quality of school districts. A_j takes a value of one if home *i* is located in MLS area number *j* and zero otherwise. Indicator variables for the quarter (Q_k) in which the transaction took place are included to control for temporal effects such as changing economic and market conditions over the 32 quarters covered by the study period. Q_k has a value of one if home *i* was sold in quarter *k* and zero otherwise. r_i is an indicator variable with a value of one if home i participated in the Rebate program and zero otherwise. $\alpha, \beta, \gamma, \zeta$ and ψ are estimated coefficients. The parameter of interest, ψ, is the average percentage premium estimated for a Rebate participant home.

3.4.2 Difference-in-differences Model

A DiD estimator is used with a sample of homes with repeat sales to assess the average impact of the Rebate program on the transaction prices of homes in Anchorage. The repeat sales sample is divided into a treatment group of homeowners who participated in the Rebate program and a control group of homeowners who did not participate in the Rebate program. Each home in the repeat sale sample sold twice over the study period from 2008 through 2015. At the time of the first sale, none of the homes in the sample had participated in the Rebate program. At the time of the second sale, the homes in the treatment group had undergone an energy efficiency retrofit through the Rebate program.

It is possible that the values of the homes of those who opted into the Rebate program differed from the homes of those who did not opt into the program. Using a DiD estimator, it is possible to determine if there is a significant difference between the values of Rebate participant and non-participant homes before the homes of Rebate participants were retrofitted. It is also possible to capture the price appreciation/depreciation trend in all housing values across the treatment and control groups in Anchorage over the study period.

In the sample, the longest possible time period between a first and second sale is seven years and eleven months since the sample covers home sales from 2008 through 2015. The short time period covered by the sample reduces the probability that homes underwent major renovations between the first and second sale. There is potential that some homes in the sample could have completed energy efficiency retrofits outside of the Weatherization or Rebate programs. However, the Weatherization program offers energy efficiency retrofits free of charge to the homeowner if the homeowner meets the income requirements, and the Rebate program offered cash reimbursement to those who completed the program. Therefore, it seems unlikely that a homeowner would have undertaken a large-scale energy efficiency retrofit without applying to one of the available residential energy efficiency programs that offered financial assistance.

The data for both first and second home sales and for both Rebate and non-Rebate participants are pooled. The effect of participating in the Rebate program on the selling price of homes is estimated with the following regression model.

$$Ln(price_i) = \alpha + \beta X_i + \sum_{j=1}^{12} \gamma_j A_j + \sum_{k=1}^{31} \zeta_k Q_k + \psi Participated_i + \omega 2ndSale_i + \delta PostRebate_i + \varepsilon_i \quad (3.2)$$

In Eq. 3.2, the dependent variable is the natural log of the selling price of home *i* in 2015 dollars. α is a constant term, X_i is a vector of hedonic characteristics of home *i* as described above, and ε_i is a random disturbance term. A_j are indicator variables taking a value of one if home *i* is located in MLS area number *j* and zero otherwise. Q_k are indicator variables taking the value one for the quarter in which home *i* was sold and zero otherwise. *Participated* is a group specific effect to control for the average pre-treatment differences between the treatment and control group. *Participated* is an indicator variable which takes a value of one if home *i* has participated or will participate in the Rebate program and zero otherwise. *2ndSale*$_i$ is the time trend. *2ndSale* takes a value of one if the transaction is the second sale of home *i* and zero otherwise. *PostRebate*$_i$ is an interaction term between *Participated* and *2ndSale* and indicates if home *i* underwent an energy efficiency retrofit through the Rebate program and was the second sale of home *i*. $\alpha, \beta, \gamma, \zeta, \psi, \omega,$ and δ are estimated coefficients. The parameter ψ accounts for the differences between homes that did and did not participate in the Rebate program. The parameter ω accounts for the changes in all housing values in Anchorage between the first and sales. The parameter of interest, δ, measures the impact of participating in the Rebate program on transaction prices of single-family homes.

$$\delta = \left(\overline{Ln(price_2)}^{Rebate} - \overline{Ln(price_1)}^{Rebate}\right) - \left(\overline{Ln(price_2)}^{Non-Rebate} - \overline{Ln(price_1)}^{Non-Rebate}\right) \quad (3.3)$$

Here the DiD estimator measures the difference in the average value of homes that participated in the Rebate program between the first and second sale minus the difference in the average value of homes that did not participate in the Rebate program between the first and second sale. The subscripts *1* and *2* indicate the first and second sale of a property, respectively. The superscripts *Rebate* and *Non-Rebate* indicate the Rebate program participation status of a property.

3.5 Data

Data on Anchorage single-family home sales from 2008 through 2015 are from the Alaska MLS. The data include information on the date of the sale and the selling price of the home. Additionally, the data include information on the hedonic characteristics of the home such as the square footage of the residence, number of bedrooms and bathrooms, whether the home has a garage, the year the home was built, whether the home is a standalone residence or a condominium, and the acreage of the property parcel.

Data on Rebate program participant properties from 2008 through 2015 are from the Cold Climate Housing Research Center (CCHRC) which manages the Alaska Retrofit Information System database on behalf of the AHFC. The data provided include the physical address of participating homes and the dates of both the as-is and post-improvement energy audit for each participant property. Data on the specific energy efficiency improvements made to the homes were not made available. The addresses of Rebate participants were matched to addresses in Alaska Multiple Listing Service dataset, and homes that sold after they participated in the Rebate program were identified. See Figure 3.2 for the distribution of Anchorage Rebate participants' pre- and post-retrofit energy efficiency ratings.

In addition to data on Rebate program participants, CCHRC also provided data on Weatherization program participants. Homes that completed the Weatherization program were removed from the dataset because these Weatherization participant homes underwent energy efficiency retrofits and therefore are not an appropriate control group. Additionally, homes that received an as-is energy efficiency audit but did not complete the Rebate program in the 18-month time requirement were also removed from dataset because it possible that their owners began, but were unable to complete, the recommended energy efficiency improvements in the allotted 18-month period. Since these homes may have undergone partial energy efficiency retrofits, they are not an appropriate control group. Homes that were less than one year old at the time of sale were removed from the dataset to eliminate new properties from the dataset since the Home Energy Rebate energy efficiency retrofit program was only available for existing homes.

In total there are 26,642 housing transactions in the sample of Anchorage single-family home sales from 2008 through 2015. The distribution of housing transactions by year, MLS area, participation in the Rebate program, Rebate homes sold by year, and decade of construction are displayed in Table 3.3. Five percent of total home transactions are Rebate participant homes. Column one of Table 3.4 reports the mean values of home characteristics for homes in the sample. The mean price of a home is $308,095 and the mean size of a home is 1,816 square feet in the full sample. The mean value of house characteristics broken out by Rebate program participation are reported in column one of Table 3.5.

In the full sample, the mean values of the characteristics of homes of those who selected into the Rebate program are different from mean values of the characteristics of the homes of those who did not select into the Rebate program. To control for these differences, one-to-three nearest neighbor propensity score matching (PSM) with replacement is used to weight the observations in the non-Rebate group so that the means of the house characteristics of the treatment and control groups are more comparable. The propensity score estimates the probability that a property participated in the Rebate program as a function of its observable characteristics. Using a logit model, the propensity scores are estimated with the home characteristics and MLS area included in the specification[5]. Each treated property is matched with three control properties based on the propensity scores. There are 4,947 homes in the PSM sample. The mean values for the house characteristics of the PSM sample are displayed in column two of Table 3.4. The average home price is $341,019 and the average home is 2,059 square feet in the PSM sample. The mean values of the house characteristics broken out by Rebate and non-Rebate participant homes are reported in column three of Table 3.5.

From the full data set, repeat sales were identified, and 4,048 homes that sold twice over the study period were extracted. Of these 4,048 homes that sold twice, 221 participated in the

[5] $\pi(x) = \frac{\exp(\alpha+\beta X_i+\sum_{j=1}^{12}\gamma_j A_j)}{1+\exp(\alpha+\beta X_i+\sum_{j=1}^{12}\gamma_j A_j)}$

Rebate program between their first and second sale. If a home participated in the Rebate program and the first and second sale of the home occurred after the date of the post-improvement energy audit, the observations were removed from the dataset. If a home sold more than twice over the study period, the two most recent sales were used. However, if a home participated in the Rebate program and sold more than twice, the two sales closest to the date of participation in the Rebate program were used. The repeat sales data is used to estimate a DiD model. The summary statistics for the repeat sales sample are reported in Table 3.6. The summary statistics broken out by Rebate participation are displayed in Table 3.7.

3.6 Results

Table 3.8 displays the results of Eq. 3.1 estimated with the full sample along with heteroscedasticity robust standard errors. Model 1 detailed in column one includes temporal and spatial fixed effects. However, the parameter estimates for the spatial and temporal fixed effects are not reported. For Model 1, the Rebate price premium is statistically significant at the one percent level which indicates that a home that participated in the Rebate program sells for an 11% price premium over similar single-family homes that did not participate in the Rebate program in Anchorage[6]. At the mean transaction price of $308,095 in the full sample for a single-family residence in Anchorage, the price premium associated with participating in the Rebate program amounts to $33,890.

In Model 1, the coefficients for the hedonic characteristics of homes are all statistically significant at the one percent level and have signs in the expected direction. The model explains 82% of the variation in the transaction prices in homes in Anchorage. Adding an additional 100

[6] The transformation of $100 * \beta$ is used for the interpretation of the coefficients for continuous variables due to the model's log-level functional form (Wooldridge, 2006). However, the transformation of $100 * [\exp(\beta) - 1]$ is used for the interpretation of the estimated coefficients of indicator variables (Halvorsen and Palmquist, 1980).

square feet to a home increases its selling price by 2% ($6,162). Adding an additional bedroom or bathroom increases a home's selling price by 4% ($12,324) and 6% ($18,486), respectively. Adding space for an additional car in a garage increases the selling price of a home by 11% ($33,890). If the property is a condominium, the selling price of the property is 31% ($95,509) lower than a standalone residence. Each additional decade of age reduces the price of a property by 4% ($12,324). Adding an additional acre to a property parcel increases the selling price of a property by 2% (6,162). As a check for robustness, Eq. 3.1 is estimated without temporal or spatial fixed effects. The results of Model 2 are reported in column 2 of Table 3.8. Here the premium associated with participating in the Rebate program is 10% ($30,810). Once again, all coefficients for the hedonic characteristics of homes are statistically significant and have signs in the expected direction. However, omitting the temporal and spatial fixed effects may result in bias parameter estimates.

The results of Eq. 3.1 estimated with the PSM sample are reported along with heteroscedasticity standard errors in column 3 of Table 3.8. All coefficients are significant at the one percent level and have signs in the expected direction. The selling price premium associated with participating in the Rebate program is 10% over similar properties that did not participate in the program. At the mean selling price of $341,019 for a single-family home in Anchorage in the PSM sample, the price premium associated with participating in the Rebate program is $34,102. Model 3 explains approximately 76% of the variation in house prices in Anchorage. The model estimated without spatial or temporal fixed effects using the PSM sample are reported in column 4 in Table 3.8 as a robustness check.

The 10% to 11% price premium for Rebate properties in the Anchorage market is less than the 15.1% to 15.5% price premium estimated in a previous study for Rebate properties in the Fairbanks market (Pride and Little, forthcoming). However, in Fairbanks the climate is considerably colder and energy prices are much higher than in Anchorage. Therefore, potential costs savings associated with energy efficient properties are likely greater in Fairbanks than Anchorage.

The results of Eq. 3.2 estimated with the repeat sales sample are reported along with heteroscedasticity robust standard errors in column one of Table 3.9. In this estimation, elevation is no longer statistically significant. All other coefficients are statistically significant at the one percent level and have the expected sign. The coefficient on *Participated* indicates that at the time of the first sale, the value of the homes purchased by homeowners who selected into the Rebate program were, on average, worth 5% ($15,305) more before they underwent the energy retrofit than similar homes whose owners did not select into the Rebate program. The coefficient on *2ndSale* indicates that, on average, after controlling for inflation and deflation across the year/quarters, the price of the second sale of homes was 8% ($24,488) greater than the price of first sale of homes. The variable of interest, *Post-Rebate*, indicates that, after controlling for differences in the first sale prices and the price appreciation trend, homes that sold after their owners participated in the Rebate program sold for an average price premium of 5% ($15,305) compared to similar homes that did not complete the Rebate program at the mean selling price of $306,107 in the repeat sales sample. This premium is smaller than the premium estimated with the hedonic model. The results of the DiD estimator indicate that part of the premium associated with participating in the Rebate program found in the hedonic analysis can be attributed to the greater initial value of the homes of those who selected into the program. The results of Eq. 3.2 estimated without spatial and/or temporal fixed effects are reported in columns 2 through 4 of Table 3.9 as a robustness check.

3.7 Conclusion

Residential energy efficiency improvements can help reduce the amount of energy required to heat homes which can save homeowners money on energy cost, reduce residential CO_2 emissions, and increase the transaction price of homes. This study uses a hedonic price framework and a DiD estimator to examine the price premium associated with participating in the Rebate program in the Anchorage housing market.

Nearly 50% (12,478) of the 25,000 homes that received energy efficiency retrofits through the Rebate program are located in Anchorage. It is estimated that Rebate participants reduce their annual CO_2 emissions by an average of 35% (10,565 pounds) (Information Insights, 2009). Thus, the energy efficiency improvements made by Rebate participants should lead to an annual reduction of approximately 60,000 metric tons of CO_2 emissions from the Anchorage residential sector. The average Rebate program participant spent $11,681 on energy efficiency improvements for their home, and the average rebate received by an Anchorage program participant was $7,422 (Ord, 2015; Waterman, 2016). After accounting for the $500 reimbursement for the as-is and post-improvement energy audits, the average out-of-pocket investment by an Anchorage Rebate program participant was $3,759. As mentioned previously, the average annual residential energy costs for an Anchorage home are $2,786, and the average Rebate participant can expect to reduce their annual energy costs by 30% (AHFC, 2014; Information Insights, 2009). Thus, the average Anchorage Rebate participant could expect to save roughly $836 annually in energy costs after retrofitting their home. Therefore, an Anchorage Rebate program participant could recoup their out-of-pocket investment in energy savings in approximately 4.5 years. The simple payback period for the combined private and public investment is 14 years.

The investment in residential energy efficiency made by Rebate program participants is compensated through a sale price premium. The results show that Anchorage residents value energy efficiency and are willing to pay a premium between 5% and 11% for energy efficient homes. It would take a homebuyer between 18 and 40 years to recoup the price premium through the average annual energy savings of $836 resulting from participating in the Rebate program. The large price premium could signal that homebuyer expect energy prices to increase in the future. The length of the payback period decreases as energy prices increase. The large price premium could also indicate that homebuyers in Anchorage place a monetary value on the reduced carbon footprint of energy efficiency properties.

Although the results are specific to homes that participated in the Rebate program, they can be applied more broadly to residential properties in Anchorage that have undergone energy efficiency retrofits. In the absence the Rebate program, investments in energy efficiency still make economic sense for homeowners in Anchorage. Homeowners who invest in energy efficiency improvements benefit immediately from energy savings stemming from the improvements, and homeowners that sell their homes after making energy efficiency improvements gain the additional benefit of receiving a premium on the selling price. The results indicate that Rebate participants who subsequently sold their homes received a price premium that exceeded the average investment in energy efficiency paid by program participants.

Future research could measure the actual energy savings resulting from energy efficiency improvements. Pre- and post-improvement energy consumption could be measured to estimate average energy savings resulting from energy efficiency retrofits. Energy savings from different categories of energy efficiency improvements such as replacing the home's heating equipment or improving its insulation could be estimated. Additionally, researchers could compare the value of the energy savings to the price premium paid by homebuyers in the market for energy efficient homes in Anchorage to learn if the energy savings are capitalized into the value of homes.

3.8 References

ACRC (Alaska Climate Research Center), Temperature Changes in Alaska, 2016. Retrieved from http://climate.gi.alaska.edu/ClimTrends/Change/TempChange.html

AHFC (Alaska Housing Finance Corporation), Home Energy Rebate Program Guidelines, 2013. Retrieved from https://www.ahfc.us/files/1913/7401/5545/HER_program_guidelines.pdf

——. Alaska Housing Assessment, 2014. Retrieved from https://www.ahfc.us/efficiency/research-information-center/housing-assessment/

Baltensperger, A., 2016. Map of Alaska with the Municipality of Anchorage shaded blue. ArcGIS.

Bloom, B., M.C. Nobe and M.D. Nobe, Valuing Green Home Designs: A study of Energy Star Homes, *Journal of Sustainable Real Estate*, 2011, 3:1, 109-126.

Boardman, B., Fixing Fuel Poverty: Challenges and Solutions, first edition, New York, NY: Earthscan, 2010.

Bond, S.A. and A. Devine, Certification Matters: Is Green Talk Cheep Talk? *Journal of Real Estate Finance and Economics*, 2016, 52, 117-140.

Brehmer, E., Budget Deficit Hits State Energy Programs, Rebates Cut, *Alaska Journal of Commerce*, March 2, 2016. Retrieved from http://www.alaskajournal.com/2016-03-02/budget-deficit-hits-state-energy-programs-rebates-cut#.WC4Rpcn-R4P

Bruegge, C., C. Carrion-Flores and J.C. Pope, Does the Housing Market Value Energy Efficient Homes? Evidence from the Energy Star Program, *Regional Science and Urban Economics*, 2016, 57, 63-76.

Chapin, F.S., S.F. Tainor, P. Cochran, H. Huntington, C. Markon, M. McCammon, A.D. McGuire, and M. Serreze, Alaska, In J.N. Melillo, T.C. Richmond, and G.W. Yohe, (eds.), Climate Change Impacts in the United States: Third National Assessment, U.S. Global Research Program, 2014.

Cerin, P., L.G. Hassel, and N. Semenova, Energy Performance and Housing Prices, *Sustainable Development*, 2014, 22, 404-419.

Dinan, T.M. and J.A. Miranowski, Estimating the Implicit Price of Energy Efficiency Improvements in the Residential Housing Market: A Hedonic Approach, *Journal of Urban Economics*, 1989, 25, 52-67.

Dodge, K., N. Wiltse, V. Valentine, Home Energy Rebate Program Outcomes, Cold Climate Research Housing Research Center, 2012.

EIA (U.S. Energy Information Administration), Heating and Cooling No Longer Majority of U.S. Home Energy Use, 2013. Retrieved from http://www.eia.gov/todayinenergy/detail.php?id=10271

——. Energy Units and Calculators Explained: Degree-Days, 2015. Retrieved from http://www.eia.gov/energyexplained/index.cfm?page=about_degree_days

——. Monthly Energy Review, October 2016.

Energy Star, History of Energy Star Guidelines for New Homes, 2016a. Retrieved from https://www.energystar.gov/index.cfm?c=new_homes.nh_history

——. Cost & Savings Estimates: ENERGY STAR Certified Homes, Version 3 (Rev. 08), 2016b. Retrieved from https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/EstimatedCostandSavings.pdf

Fuerst, F., E. Oikarinen, and O. Harjunen, O., Green Clientele Effects in the Helsinki Metropolitan Area Housing Market, City of Helsinki Urban Facts Working Papers 2016:3.

Goldsmith, S., S. Pathan, N. Wiltse, Snapshot: The Home Energy Rebate Program, Institute for Social and Economic Research, University of Alaska Anchorage, 2012.

Halvorsen, R., and R. Palmquist, The Interpretation of Dummy Variables in Semilogarithmic Equations. *The American Economic Review*, 1980, 70:3, 474-475.

Hoen, B., R. Wiser, P. Cappers and M. Thayer, An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sale Prices in California, Lawrence Berkley National Laboratory, Environmental Energy Technologies Division Report LBNL-4476E, June 24, 2011, 1:60.

Indiana University Bloomington, Green Building Background, 2016. Retrieved from http://sustain.indiana.edu/programs/green-building/background.

Information Insights, Alaska housing assessment: Part I and II, 2009. Retrieved from http://www.cchrc.org/docs/reports/TR_2009_02_2009_AK_Housing_Assessment_Final.pdf

IPCC (International Panel on Climate Change), Climate Change 2014: Synthesis Report, In Pachauri, R.K., and L.A. Meyers, (eds.), Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014.

Kahn, M.E., and N. Kok, The Capitalization of Green Labels in the California Housing Market, *Regional Science and Urban Economics*, 2014, 47, 25-34.

Kats, G., L. Alevantis, A. Berman, E. Mills, and J. Perlman. The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force. October, 2003

Laquatra, J., D.J. Dacquisto, P. Emrath, and J.A. Laitner, Housing market capitalization of energy efficiency revisited. Proceedings of the 2002 American Council for an Energy Efficient Economy (ACEEE) Summer Study of Energy Efficiency in Buildings, August 2002.

Lechner, M., The Estimation of Causal Effects by Difference-in-Difference Methods, *Foundations and Trends in Econometrics*, 2010, 4:3, 165-224.

Mandell, S. and M. Wilhelmsson, Willingness to Pay for Sustainable Housing. *Journal of Housing Research*, 2011, 20:1, 35-51.

Matthiessen, L.F. and P. Morris. Costing Green: A Comprehensive Cost Database and Budgeting Methodology. Retrieved from: http://www.davislangdon.com/upload/images/ publications / USA / 2004%20Costing%20Green%20Comprehensive%20Cost%20Database. pdf. 2004.

——. Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption. Retrieved from: http: / / www.davislangdon.com / upload / images / publications / USA / The%20Cost%20of% 20Green%20Revisited.pdf. July 2007.

Ord, J., Committee minutes. Alaska State Legislature House Special Committee on Energy, January 27, 2015. Retrieved from http://www.legis.state.ak.us/basis/get_single_minute.asp?session=29&house=H&comm=ENE&date=20150127&time=1019

Pride, D, and J. Little, The Value of Residential Energy Efficiency in Interior Alaska: A Hedonic Pricing Analysis, forthcoming.

Reichard, A., F. Fuerst, N.B. Rottke and J. Zietz, Sustainable Building Certification and the Rent Premium: A Panel Data Approach, *Journal of Real Estate Research*, 2012, 34:1, 99-126.

Rosen, S., Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy*, 1974, 82:1, 34-55.

Saylor, B., S. Haley, N. Szymoniak, Estimated Household Costs for Home Energy Use, May 2008. Institute of Social and Economic Research, University of Alaska Anchorage, 2008.

Sivak, M., Air Conditioning Versus Heating: Climate Control is More Energy Demanding in Minneapolis than Miami. *Environmental Research Letters*, 2013, 8:1, 1-4.

Tichotsky, J., Alaska State Revenues: Overview, History, and Forecast Alaska Department of Revenue Forum on Alaska's Fiscal Future, October 2014. Retrieved from http://akcommonground.org/wp-content/uploads/2014/10/Tichotsky-John-Alaska-State-Revenues-for-Oct-4-2014-Fiscal-Future-Forum.pdf

U.S. Census Bureau, QuickFacts: Anchorage Municipality, Alaska (County), 2016. Retrieved from http://www.census.gov/quickfacts/table/EDU635214/02020.

U.S. Department of Energy, Building Energy Codes Program: Alaska, 2016. Retrieved from https://www.energycodes.gov/adoption/states/alaska

Walls, M., K. Palmer, T. Gerarden and X. Bak, Is Energy Efficiency Capitalized into Home Prices? Evidence from Three US Cities, Resources for the Future Discussion Paper 13-18-REV, February 2016.

Waterman, S., Alaska Housing Finance Cooperation State Energy Program Manager, e-mail message to author, October 20, 2016.

Wilson, M., B. Saylor, N. Szymoniak, S. Colt, G. Fay, Components of Delivered Fuel Prices in Alaska, Institute of Social and Economic Research, University of Alaska Anchorage, 2008.

Wooldridge, J., Introductory Econometrics: A Modern Approach, third edition, Mason: Thompson South-Western, 2006.

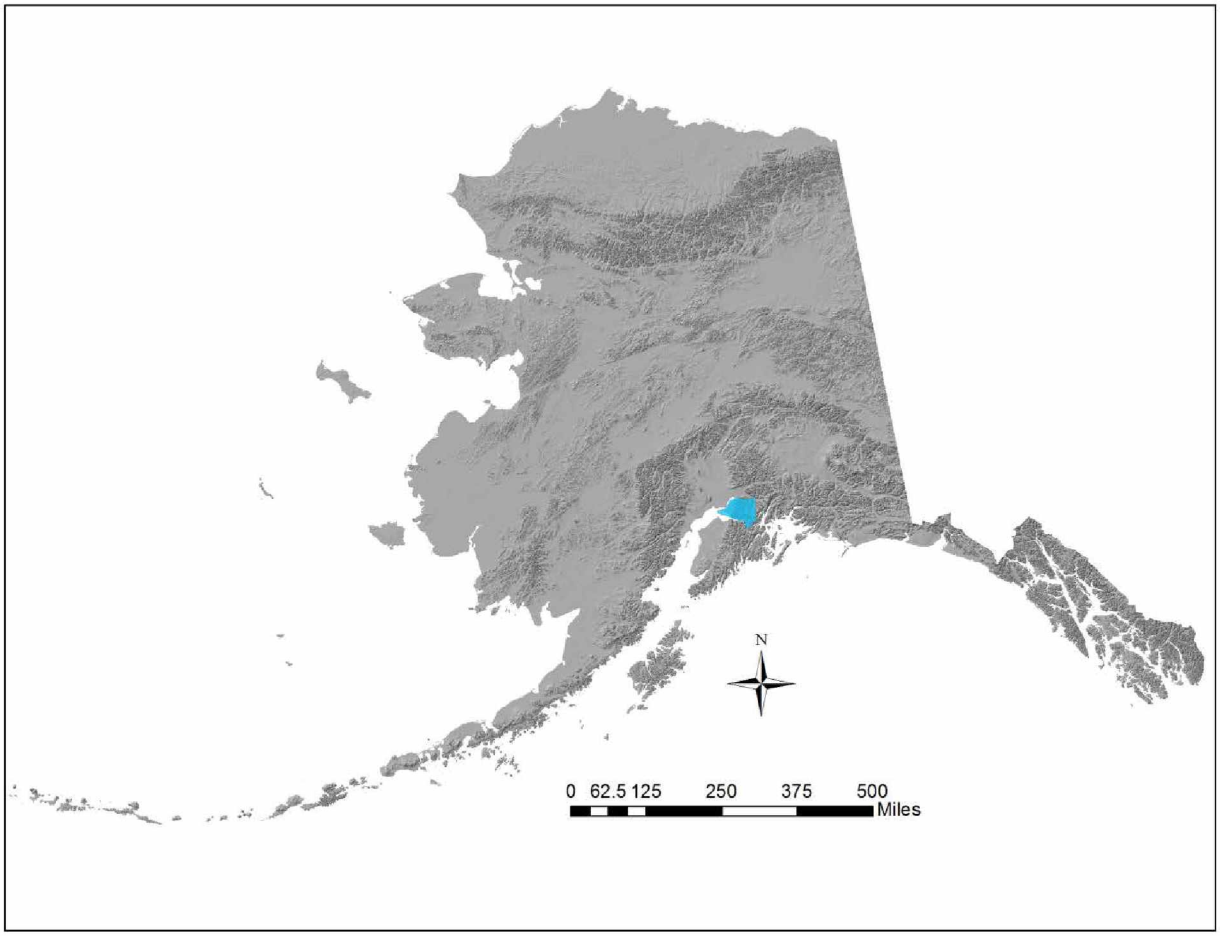

Figure 3.1. Map of Alaska with the Municipality of Anchorage shaded blue (Baltensperger, 2016)

Table 3.1. Point values for energy ratings

Points	Ratings
0-39	1 Star
40-49	1 Star +
50-59	2 Star
60-67	2 Star +
68-72	3 Star
73-77	3 Star +
78-82	4 Star
83-88	4 Star +
89-91	5 Star
92-94	5 Star +
95-100+	6 Star

Table 3.2. Maximum possible rebate by steps

Steps	Maximum Possible Rebate
1 Steps	$4,000
2 Steps	$5,500
3 Steps	$7,000
4 Steps	$8,500
5 Steps	$10,000

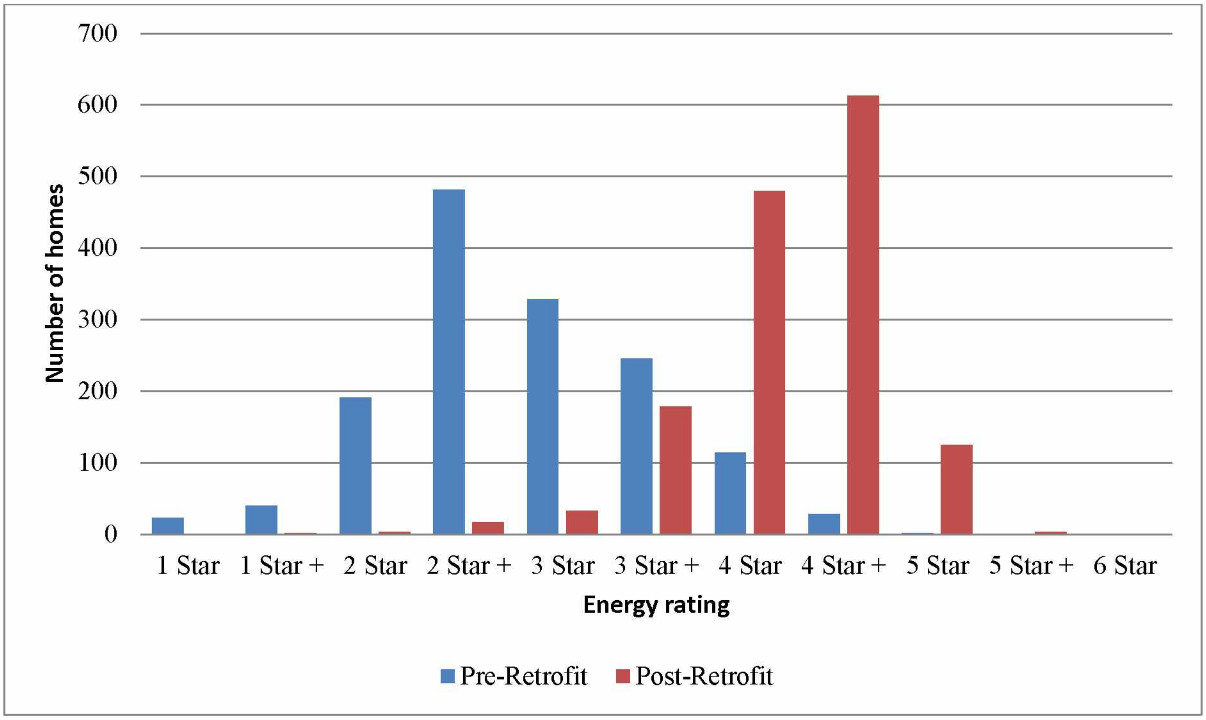

Figure 3.2. Distribution of Rebate participants' pre- and post- retrofit energy ratings.

Table 3.3. Distribution of housing transactions

A. Distribution of housing transactions by year		
Year	Frequency	Percentage
2008	3,310	12%
2009	3,141	12%
2010	2,966	11%
2011	2,880	11%
2012	3,195	12%
2013	3,702	14%
2014	3,641	14%
2015	3,807	14%
Total	26,642	100%
B. Distribution of housing transactions by MLS area		
MLS Area	Frequency	Percentage
5-Downtown	774	3%
10-Spendard	1,745	7%
15-West Tudor Road-Diamond Boulevard	3,482	13%
20-Dimond South	2,916	11%
25-Dearmoun Road-Potter Marsh	888	3%
30-Abbot Road-Dearmoun Road	3,053	11%
35-East Tudor Road-Abbot Road	2,676	10%
40-Seward Highway to Boniface Parkway	2,261	8%
45-Boniface Parkway to Muldoon Road	3,900	15%
50-Post Road-Glenn Highway	137	1%
90-Eagle River	3,659	14%
100-Chugiak/Peters Creek	790	3%
101-Girdwood-Turnagain Arm	361	1%
Total	26,642	100%
C. Distribution of housing transactions by participation in the Home Energy Rebate Program		
Rebate	Frequency	Percent
0	25,186	95%
1	1,456	5%
Total	26,642	100%

Table 3.3. continued

D. Distribution of Rebate participant housing transactions by year		
Year	Frequency	Percentage
2008	3	0%
2009	21	1%
2010	66	5%
2011	145	10%
2012	224	15%
2013	317	22%
2014	320	22%
2015	360	25%
Total	1,456	100%
E. Distribution of housing transactions by decade of construction		
Year	Frequency	Percent
Pre-1950	133	0%
1950-1959	847	3%
1960-1969	1,596	6%
1970-1979	5,695	21%
1980-1989	8,050	30%
1990-1999	3,200	12%
2000-2009	6,086	23%
Post-2009	1,035	4%
Total	26,642	100%

Table 3.4. Mean values of home characteristics

Variable	Definition	Full sample (1)	PSM sample (2)
Price	Transaction price of the property	308,095	341,019
		(149,992)	(126,469)
lnRprice	Natural log of transaction price	12.53	12.68
		(0.46)	(0.35)
Rebate	Indicator variable for Rebate participation	0.055	0.294
		(0.227)	(0.46)
Square feet	Square footage of the residence	1,816	2,059
		(863)	(818)
Bedrooms	Number of bedrooms	3.10	3.43
		(0.90)	(0.80)
Bathrooms	Number of bathrooms	2.14	2.28
		(0.72)	(0.71)
Garage Capacity	Number of cars a garage can hold	1.60	1.73
		(0.96)	(0.89)
Condo	Indicator variable for condominium	0.29	0.001
		(0.46)	(0.03)
Age	Age of property at sale	25.07	34.67
		(14.73)	(12.03)
Acres	Acreage of the property	0.24	0.33
		(0.78)	(0.40)

Note: Standard deviation in parentheses

Table 3.5. Mean values of home characteristics by Home Energy Rebate participation

Variable	Definition	Rebate Status	Full sample Mean	Std. Dev.	PSM sample Mean	Std. Dev.
			(1)	(2)	(3)	(4)
Price	Transaction price of the property	Rebate = 1	359,741	107,639	359,741	107,639
		Rebate = 0	305,109	151,544	333,215	132,759
lnRprice	Natural log of transaction price	Rebate = 1	12.76	0.27	12.76	0.27
		Rebate = 0	12.52	0.46	12.65	0.37
Square feet	Square footage of the residence	Rebate = 1	2,079	701	2,079	701
		Rebate = 0	1,802	875	2,051	863
Bedrooms	Number of bedrooms	Rebate = 1	3.43	0.71	3.43	0.71
		Rebate = 0	3.08	0.90	3.42	0.83
Bathrooms	Number of bathrooms	Rebate = 1	2.30	0.63	2.30	0.63
		Rebate = 0	2.14	0.73	2.27	0.74
Garage capacity	Number of cars a garage can hold	Rebate = 1	1.78	0.78	1.78	0.78
		Rebate = 0	1.59	0.97	1.71	0.93
Condo	Indicator variable for condominium	Rebate = 1	0.001	0.03	0.001	0.03
		Rebate = 0	0.31	0.46	0.001	0.03
Age	Age of property during the year of sale	Rebate = 1	34.80	10.25	34.80	10.25
		Rebate = 0	24.51	14.76	34.62	12.70
Acres	Acreage of the property	Rebate = 1	0.34	0.40	0.34	0.40
		Rebate = 0	0.24	0.79	0.32	0.40

Table 3.6. Summary statistics (repeat sales)

Variable	Definition	Mean	Std. Dev.	Min.	Max.
Price	Transaction price of the property	306,107	147,760	23,913	1,822,160
lnRprice	Natural log of transaction price	12.53	0.46	10.08	14.42
Participated	Participated or will participate in Rebate program	0.05	0.23	0.00	1.00
Square feet	Square footage of the residence	1,799	861	409	11,455
Bedrooms	Number of bedrooms	3.10	0.90	1.00	11.00
Bathrooms	Number of bathrooms	2.15	0.72	0.75	13.00
Garage capacity	Number of cars a garage can hold	1.62	0.95	0.00	10.00
Condo	Indicator variable for condominium	0.30	0.46	0.00	1.00
Age	Age of property at sale	24.43	13.88	1.00	95.00
Acres	Acreage of the property	0.22	0.63	0.00	24.21

Table 3.7. Summary statistics by Home Energy Rebate program participation (repeat sale sample)

Variable	Definition	Rebate Status	Mean	Std. Dev.	Min.	Max.
Price	Transaction price of the property	Rebate = 1	353,104	96,607	135,000	735,872
		Rebate = 0	304,788	148,733	23,913	1,822,160
lnRprice	Natural log of transaction price of the property	Rebate = 1	12.74	0.27	11.81	13.51
		Rebate = 0	12.52	0.46	10.08	14.42
Square feet	Square footage of the residence	Rebate = 1	2,019	698	720	4,656
		Rebate = 0	1,793	864	409	11,455
Bedrooms	Number of bedrooms	Rebate = 1	3.45	0.77	2.00	6.00
		Rebate = 0	3.09	0.90	1.00	11.00
Bathrooms	Number of bathrooms	Rebate = 1	2.23	0.65	1.00	4.00
		Rebate = 0	2.14	0.73	0.75	13.00
Garage capacity	Number of cars a garage can hold	Rebate = 1	1.60	0.83	0.00	5.00
		Rebate = 0	1.62	0.96	0.00	10.00
Condo	Indicator variable for condominium	Rebate = 1	0.00	0.00	0.00	0.00
		Rebate = 0	0.31	0.46	0.00	1.00
Age	Age of property at sale	Rebate = 1	35.74	11.05	3.00	72.00
		Rebate = 0	24.11	13.82	1.00	95.00
Acres	Number of acres of the property	Rebate = 1	0.27	0.28	0.07	2.76
		Rebate = 0	0.22	0.63	0.00	24.21

Table 3.8. Results from hedonic regressions (full and PSM samples)

Dependent variable: Ln(Sale Price)				
	Full sample		PSM sample	
	Model 1:	Model 2:	Model 3:	Model 4:
Rebate	**0.106*****	**0.094*****	**0.097*****	**0.093*****
	(0.004)	**(0.004)**	**(0.005)**	**(0.005)**
Square feet	0.020***	0.023***	0.019***	0.021***
	(0.001)	(0.001)	(0.001)	(0.001)
Bedrooms	0.037***	0.016***	0.021***	0.015**
	(0.003)	(0.003)	(0.006)	(0.006)
Bathrooms	0.063***	0.072***	0.045***	0.048***
	(0.004)	(0.005)	(0.008)	(0.008)
Garage capacity	0.113***	0.107***	0.086***	0.088***
	(0.002)	(0.003)	(0.004)	(0.005)
Condo	-0.269***	-0.246***	-0.323***	-0.234***
	(0.004)	(0.004)	(0.066)	(0.064)
Age	-0.004***	-0.004***	-0.003***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Acres	0.018***	0.015***	0.098***	0.083***
	(0.006)	(0.004)	(0.011)	(0.010)
Constant	12.240***	11.907***	12.316***	11.955***
	(0.017)	(0.010)	(0.089)	(0.024)
Quarter FE	Yes	No	Yes	No
MLS area number FE	Yes	No	Yes	No
Observations	26,642	26,642	4,947	4,947
R-squared	0.821	0.779	0.761	0.716
AIC	-11,744	-6,207	-3,999	-3,237
BIC	-11,318	-6,133	-3,667	-3,178

Notes: Heteroscedasticity robust standard errors are reported in parentheses. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Table 3.9. Results from difference-in-differences estimation (repeat sales sample)

Dependent variable: Ln(Sale Price)				
	Model 1:	Model 2:	Model 3:	Model 4:
Participated	0.048***	0.059***	0.045***	0.056***
	(0.011)	(0.011)	(0.012)	(0.012)
2ndSale	0.076***	0.042***	0.079***	0.041***
	(0.007)	(0.005)	(0.008)	(0.005)
PostRebate	**0.051*****	**0.041*****	**0.050*****	**0.040****
	(0.014)	**(0.014)**	**(0.016)**	**(0.016)**
Square feet	0.020***	0.020***	0.023***	0.023***
	(0.001)	(0.001)	(0.001)	(0.001)
Bedrooms	0.048***	0.049***	0.025***	0.026***
	(0.004)	(0.004)	(0.005)	(0.005)
Bathrooms	0.041***	0.040***	0.042***	0.042**
	(0.015)	(0.016)	(0.016)	(0.016)
Garage capacity	0.125***	0.123***	0.120***	0.119***
	(0.007)	(0.007)	(0.007)	(0.007)
Condo	-0.268***	-0.270***	-0.251***	-0.252***
	(0.008)	(0.008)	(0.009)	(0.009)
Age	-0.004***	-0.004***	-0.003***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
Acres	0.015	0.014	0.009	0.008
	(0.012)	(0.012)	(0.012)	(0.012)
Constant	12.263***	12.254***	11.906***	11.890***
	(0.046)	(0.045)	(0.036)	(0.035)
Quarter FE	Yes	No	Yes	No
MLS area number FE	Yes	Yes	No	No
Observations	8096	8096	8096	8096
R-squared	0.835	0.829	0.800	0.794
AIC	-4,207	-3,978	-2,670	-2,496
BIC	-3,829	-3,817	-2,376	-2,419

Notes: Heteroscedasticity robust standard errors are reported in parentheses. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively.

Chapter 4

The Value of Residential Energy Efficiency in Two Alaska Property Markets[1]

Abstract

Residential energy efficiency is a salient issue in Alaska where residents in many of the state's regions face high home energy costs due to the combination of high energy prices and the cold climate. This paper explores the relationship between energy efficiency ratings and the transaction prices of single-family homes in two Alaska housing markets during the period between 2008 and 2015. Hedonic models are used to test whether energy efficiency ratings significantly affect property prices in the Anchorage and Fairbanks housing markets. The results from the robust regressions suggest that homes with above-average energy efficiency ratings command a price premium in both markets. In the Anchorage market, homes with above-average energy efficiency ratings sell for a price premium between 1.8% and 6.0%, whereas homes with below-average energy efficiency ratings sell for a discount between 1.3% and 7.4%. In the Fairbanks market, homes with above-average energy efficiency ratings sell for a premium between 6.9% and 17.5%, whereas homes with below-average energy efficiency ratings sell for a discount between 5.0% and 13.3%.

4.1 Introduction

Energy efficiency ratings reduce information asymmetry between property buyers and sellers (Kahn and Kok, 2014; Walls et al., 2016). Energy efficiency ratings provide homebuyers with valuable information regarding the potential energy costs associated with a property and provide home sellers with a means of signaling the energy efficiency of their properties. Energy

[1] Pride, D., Little, J., 2017. The Value of Energy Efficiency in Two Alaska Property Markets. Prepared for submission to Energy Policy.

ratings are especially valuable in cold climate regions where demand for residential space heating is high due to the correlation between heating degree days[2] and energy consumption (Energy Information Administration (EIA), 2015). Compared to the national average, energy costs in many regions of Alaska are high (EIA, 2016). The combination of a cold climate and high energy prices often leads to high home energy costs for Alaska households. Improving the energy efficiency of the housing stock can reduce the amount of energy needed for home heating thereby decreasing homeowners' energy costs and CO_2 emissions (Boardman, 2010).

Despite the state's cold climate, Alaska does not currently have a mandatory statewide energy efficiency standard for residential buildings. However, the state implemented a voluntary energy efficiency certification program, the Alaska Housing Finance Corporation[3] (AHFC) Building Energy Efficiency Standard (BEES) in 1992[4] (AHFC, 2013a). BEES sets building energy use standards for thermal resistance, moisture protection, air leakage and ventilation (AHFC, 2013b). However, approximately 75% of the housing stock in both Anchorage and Fairbanks was constructed prior to the implementation of BEES (AHFC, 2014).

As energy prices climbed to record highs in 2008, the Alaska State Legislature sought to mitigate the burden of high home energy costs by appropriating $300 million in funding for two residential energy efficiency programs administered by the AHFC, the Weatherization program and the Home Energy Rebate (Rebate) program (Alaska Journal of Commerce, 2008). The Weatherization program provides energy upgrades to dwellings at no cost to homeowners and renters who meet income qualifications (Goldsmith et al., 2012). The Rebate program was

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[2] Heating degree days are the annual sum of the difference between a base temperature (typically 65°F) and the average outdoor air temperature over a 24-hour period (EIA, 2015).
[3] The Alaska Housing Finance Corporation is a public corporation that administers public and senior housing programs, provides affordable loans for housing and administers energy efficiency and weatherization programs.
[4] In order to qualify for financing through the AHFC, homes built after 1991 must be in compliance with the version of BEES that was in effect at the time of its construction.

established for homeowners who did not meet the income qualifications of the Weatherization program. Through the Rebate program, homeowners could receive a rebate up to $10,000 for preapproved energy efficiency improvement made to their home. The Rebate program operated from 2008 through early 2016 when the program was suspended due to state budgetary shortfalls (Brehmer, 2016). Homeowners wishing to participate in either the Weatherization program or the Rebate program were required to undergo both an as-is and post-improvement energy audit to determine the energy efficiency rating of their home before and after energy efficiency improvements were completed. For Rebate participants, the amount of the rebate was contingent upon improvement in the home's energy efficiency rating between the as-is and the post-improvement audit.

To determine a home's energy efficiency rating, the AHFC uses the Home Energy Rating System index which is the nationally recognized system for inspecting and calculating a home's energy performance (AHFC, 2013b). Energy raters authorized by the AHFC use a computer-simulation based home energy rating system software, AkWarm, to model the energy efficiency of residential buildings. The energy rating score is based on a comparison between the rated building and a hypothetical reference building meeting energy efficiency standards with the same dimensions as the rated building. A home's energy rating score[5] is based on a zero to 100+ point scale which corresponds to a star rating scale ranging from 1 Star to 6 Stars[6] (See Table 4.1). The higher the energy rating score, the closer the rating building is to the energy efficiency standard

[5]The energy rater performs a blower door test to assess the airtightness of the residence, a combustion safety test to ensure all combustion appliances are operating safely at their rated efficiency level, and a ventilation assessment. The energy rater also conducts an on-site assessment of the interior and exterior of the building. The energy rater enters all relevant information into the AkWarm software which yields an energy rating score for the building.
[6] It should be noted that the AHFC energy star rating is not related to the U.S. Environmental Protection Agency's Energy Star certification program.

of the reference building based on the rated building's size, shape, and fuel mix among other factors.

In this study, a hedonic pricing framework is used to analyze the relationship between energy efficiency rating and the transaction price of single-family homes in the Municipality of Anchorage (Anchorage) and the Fairbanks North Star Borough (Fairbanks) housing markets using a sample of homes that received energy efficiency ratings through participating in either the Weatherization or Rebate programs and were later sold during the time period between 2008 and 2015. The premium a homebuyer is willing to pay for an energy efficient home should be equal to or less than the present value of their expected energy savings over their anticipated tenure in the home. Accordingly, a homebuyer should be willing to pay a larger price premium for a home with a higher energy efficiency rating because of the larger potential energy savings associated with a more energy efficient home.

Figure 4.1 displays the estimated household energy consumption by energy efficiency rating for the Anchorage and Fairbanks homes in the AHFC's Alaska Retrofit Information System database (Waterman, 2017). As the energy efficiency rating of a home increases the energy consumed per square foot decreases. In Anchorage and Fairbanks, energy consumption per square foot is comparable for homes with like energy efficiency ratings. However, as displayed in Figure 4.2, estimated annual energy expenditures[7] for homes in each energy efficiency category are far greater for Fairbanks homes than Anchorage homes because of differences in the primary fuel type used and energy prices between the two cities.

[7] The average annual energy expenditure is based on the average size home in the Alaska Retrofit Information System database for Anchorage (2,177 square feet) and Fairbanks (2,163 square feet), and on current energy prices in Anchorage (16.67¢/kWh for electricity and $9.64/Mcf for natural gas) and Fairbanks (19.89¢/kWh for electricity and $2.65/gallon #2 heating oil) (Alaska DCCED, 2016; EIA, 2017; GVEA, 2017; ML&P, 2017).

This paper makes two contributions to the literature relating energy efficiency and residential property sale prices. This is the first study to investigate the relationship between energy efficiency ratings and housing prices in Alaska housing markets. Second, this paper contributes to the small body of literature investigating residential energy efficiency and property prices in cold climate regions (Cerin et al., 2014; Fuerst et al., 2016; Mandell and Wilhelmsson, 2011). Energy efficiency improvements can have a larger impact on cost savings in cold climate regions relative to regions with more temperate climates because households in cold climate regions typically consume more energy, largely due to demand for home heating, than households in more temperate climates (Sivak, 2013).

The remainder of this paper is structured as follows: Section 4.2 provides a review of the relevant literature, and Section 4.3 provides background on the study areas of Anchorage and Fairbanks. The methods are outlined in Section 4.4, the data are described in Section 4.5, and the results are presented in Section 4.6. Section 4.7 covers the conclusion and policy implications of the research.

4.2 Literature Review

There is a growing body of literature relating energy efficiency and property prices using the hedonic pricing framework. Many early studies focused on commercial transactions (Wiley et al., 2010; Eichholtz et al., 2010; Fuerst and McAllister, 2011; Reichardt et al., 2012). However, more recently, many studies focus on residential transactions. The establishment of energy efficiency certifications which provide potential buyers with information about the relative energy efficiency of properties have made it less difficult to study the impact of energy efficiency on property prices. In the United States, two national energy efficiency certifications are the Energy Star certification and the Leadership in Energy and Environmental Design (LEED) certification. In 1995, the United States Environmental Protection Agency created the Energy Star certification program for newly constructed homes that used 20% less energy than typical newly constructed homes (Energy Star, 2016). Bloom et al. (2011) compare Energy Star certified home sale prices to non-Energy Star certified home prices using a sample of 300 home sales in Fort Collins, Colorado from 1999 to 2005. The authors find Energy Star certified homes sell for a premium of $8.66 per square foot over comparable non-Energy Star certified homes.

The LEED certification was developed in 1998 by the U.S. Green Building Council in order to rate the design, construction, operation and maintenance of green buildings (Indiana University Bloomington, 2016). Unlike the Energy Star certification, the LEED certification is broken out into tiers ranging from basic certification for properties that meet the minimum LEED standards to Platinum certification for properties that meet the most stringent energy efficiency and environmental standards. Bond and Devine (2016) examine the rental rates of green multi-family properties across the United States. Properties that are labeled as green, but are not LEED certified command a 7.6% rent premium over non-green properties. However, properties that are LEED certified achieve a larger premium (8.9%) over similar non-certified properties than non-certified properties merely labeled as green.

Kahn and Kok (2014) use a sample of 1.6 million single-family home sales in California from 2007 through 2012 to investigate the impact of several different green ratings (Energy Star, LEED, and California's GreenPoint Rated) on home prices. The authors find that homes with a green rating sell for a 5.3% price premium over comparable non-rated homes. However, when the sample is restricted to the Metropolitan Statistical Areas of Los Angeles, San Diego, and San

Francisco and the green ratings are broken out by green rating standard, only the Energy Star premium (4.7%) remains statistically significant.

Walls et al. (2016) examine whether energy efficiency is capitalized into home prices across three metropolitan areas: Austin, Texas; Portland, Oregon; and the Research Triangle area of North Carolina. The authors focus on both the national Energy Star certification and local green certifications in Austin and Portland. They use a sample of over 170,000 sales of single-family homes from 2005 through 2011. The results indicate that Energy Star certifications are associated with a price premium of 2% in the Portland and Research Triangle markets. The respective local green certifications are associated with a 7% to 8% premium in Austin and a 3% premium in Portland over comparable non-certified properties.

Many studies relating residential energy efficiency to property price premiums in European property markets focus on energy performance certificates (EPCs), which rate properties based on their energy efficiency on a scale from A to G with A being the most energy efficient and G being the least. Following the passage of the 2003 EU Energy Performance of Building Directive establishing a common energy efficiency rating methodology across the European Union, energy performance certificates must be made available when buildings are constructed, rented, or sold (EUR-Lex, 2007).

Hyland et al. (2013) analyze the impact of EPC ratings on residential property sale and rental prices in Ireland. Using data that covered sales (397,258) and rental listings (888,211) from January 2008 through March 2011, the authors find that compared to properties with a D efficiency rating, properties with A, B, and C ratings commanded sales premiums of 9.3%, 5.5%, and 1.7%, respectively. Properties with E and F/G ratings sold at a discount of 0.4% and 10.6%, respectively, compared to properties with D ratings. Regarding rental prices, properties with A and B energy efficiency ratings commanded rent premiums of 1.8% and 3.9% respectively compared to properties with D ratings. However, properties with C, E, and F/G energy efficiency ratings, rented at a discount of 0.6%, 1.9%, and 3.2%, respectively when compared to properties with D efficiency ratings. Also focusing on Ireland, Davis et al. (2015) investigate the relationship between energy performance and residential property sale price in the Belfast market using a hedonic pricing framework. A sample of nearly 4,000 residential property transactions is used to determine the effect of EPCs on property values. Compared to properties with a D rating, properties with B and C ratings commanded significant price premiums of 25% and 5%, respectively. However, there were no statistically significant differences between properties with D ratings and properties with E, F, or G ratings. There were no properties in the sample with A ratings.

Fuerst et al. (2015) apply both a hedonic regression and a modified repeat sales regression to a sample of over 333,000 dwellings in England that sold at least twice from 1995 through 2012. The authors find a positive relationship between energy performance rating and sale price. Compared to dwellings with D ratings, dwellings with A/B ratings command a 5% premium, and dwellings with C ratings command a 1.8% premium. Dwellings with E and F ratings sell for a discount of 0.7% and 0.9%, respectively. The results of the repeat sales regression indicate that, compared to dwellings with D ratings, dwellings with C ratings appreciate at a higher rate, but dwellings with A/B ratings experience price depreciation as do dwellings with E and F ratings. To determine whether energy efficiency is capitalized into property prices in the Spanish housing market, de Ayala et al. (2016) determine the EPC rating of over 1,500 dwellings via household survey. Applying the hedonic pricing framework, the authors find that homes with the highest energy efficiency ratings sell for a premium between 5.4% and 9.8% compared to similar homes with lower energy efficiency ratings.

Studies focusing on cold climate regions are of particular relevance to this study. Cerin et al. (2014) analyze a sample of over 16,000 private housing transactions from 2009 to 2010 to determine if mandatory EPCs have an impact on housing prices in Sweden. The authors find that a 1% increase in the energy efficiency of a property is associated with a 0.06% increase in the selling price. Fuerst et al. (2016) examine the impact of energy ratings on the transaction prices of apartments in Helsinki from 2009 through 2012. The authors find that apartments with A, B, or C energy performance ratings are associated with a 3.3% price premium over similar properties with lower energy ratings. However, when the authors control for detailed neighborhood characteristics, the price premium is reduced to 1.5%.

An example of an energy efficiency certification program in an Asian housing market is Singapore's Green Mark certification which was established in 2005 by Singapore's Building and Construction Authority and became mandatory for new buildings in 2008. Through the program, buildings are assessed and awarded points for energy efficiency and the incorporation of environmentally-friendly features. Addae-Dapaah and Chieh (2011) estimate the economic impact of the Green Mark certification on Singapore's residential sector. Using data on 13,899 sales from July 2005 through June 2009, the authors find Green Mark certified buildings command a 13% premium over non-certified properties. The authors break out the Green Mark certification into different levels and find that the highest level of certification, Platinum, is associated with a 28% price premium while the Gold Plus and Gold certifications are each associated with a 10% premium compared to non-certified properties. Also focusing on the Green Mark certifications in Singapore, Deng et al. (2012) find that Green Mark certified properties sell for a 4% price premium over similar, non-certified properties. When the Green Mark certification is broken out into levels, the analysis shows that Platinum certification is associated with a 14% price premium. In general, the literature suggests there is a significant positive value placed on energy efficiency in housing markets across many nations.

4.3 Study Areas

4.3.1 Anchorage

Anchorage is located in south central Alaska. See Figure 4.3. Anchorage is the state's largest city with nearly 300,000 residents (U.S. Census Bureau, 2016). The city has a subarctic climate with maritime influences. The average annual temperature is 3°C (37°F); the mean January and July temperatures are -8°C (17°F) and 15°C (59°F), respectively (ACRC, 2016). Annually, Anchorage averages 10,570 heating degree days (Information Insights, 2009). The city is located within close proximity to the Cook Inlet gas fields providing the city with access to natural gas. Over 90% percent of Anchorage homes use natural gas for space heating (AHFC, 2014). The percentage of total residential energy use dedicated to space heating in Anchorage is 72%, compared to the national average of 42% (AHFC, 2014; EIA, 2013). At $2,786 per year, average household energy costs in Anchorage are 30% above the national average (AHFC, 2014). Regarding the housing stock, the average home in Anchorage is 1,888 square feet and uses 143,000 British thermal units[8] (Btu) per square foot for space heating (AHFC, 2014). The average home heating index[9] is 9.8, and average energy rating for residential properties is 3 Stars (AHFC, 2014).

[8] A British thermal unit (Btu) is the amount of work required to raise a pound of water one degree Fahrenheit.
[9] The home heating index is the Btu used per square foot per year divided by the annual total heating degree days.

4.3.2 Fairbanks

Fairbanks is located in Interior Alaska. See Figure 4.3. The largest city in the borough is the City of Fairbanks with approximately 32,000 residents (U.S. Census Bureau, 2015). The city has a subarctic climate but without the moderating effect of maritime influences, Fairbanks has colder winters and warmer summers than Anchorage. The average annual temperature in Fairbanks is -2°C (28° F); the mean January and July temperatures are -22°C (-8°F) and 17°C (63°F), respectively (ACRC, 2016). Fairbanks averages 13,669 heating degree days annually, 23% more than Anchorage (Information Insights, 2009). Unlike Anchorage, few Fairbanks residents have access to natural gas for home heating. Nearly 90% percent of Fairbanks households use fuel oil for home heating (AHFC, 2014). At $8,110 per year, home energy costs in Fairbanks are 3.8 times above the national average and 2.9 times above the Anchorage average (AHFC, 2014). The average Fairbanks home is 1,844 square feet and uses 141,000 Btu per square foot for home heating (AHFC, 2014). In Fairbanks, 80% of household energy consumption is dedicated to space heating (AHFC, 2014). The average home heating index in Fairbanks is 7.7. Like Anchorage, the average energy rating for the housing stock in Fairbanks is also 3 Stars (AHFC, 2014).

4.4 Methods

In both the Anchorage and Fairbanks samples, relatively few homes have energy star ratings at either end of the scale. Because there are few observations with 1 Star, 1 Star+, 5 Star or 5 Star+ energy ratings, outliers or influential observations in these energy rating categories can bias the parameter estimates for these categories. In addition to OLS, robust regression is used to estimate the hedonic equations to control for potential bias that outliers can introduce.

Robust regression is a technique that mitigates the impact of outliers on regression coefficients by using weights to diminish the influence of outlying observations.

Stata software[10] is used to estimate the models. Stata's robust regression uses iteratively reweighted least squares (Verardi and Croux, 2009). First an OLS regression is run, and the Cook's distance of each observation is calculated. Cook's distance measures the impact of removing an observation on the regression parameters and is useful for identifying outliers in the values of the independent variables as well as the influence of each observation of the fitted values of the dependent variable. Observations with Cook's distances greater than one are given a weight of zero. Then both Huber weights and biweights are used because, used alone, Huber weights can have problems with severe outliers and biweights can fail to converge or may yield multiple solutions (Stata, 2013). The weights are iteratively calculated based on the absolute value of the residuals until the maximum change in the weight is below tolerance. In Huber weighting, observations that have small residuals are given a weight of one, and larger residuals are given progressively smaller weights. With biweights, all observations with a nonzero residual receive at least some downweighting.

The hedonic pricing framework relates the transaction price of a home to its individual attributes allowing the contribution of each attribute to be isolated (Rosen, 1974). A standard hedonic real estate valuation framework is employed to relate the transaction price of a home to its geographic location, time of sale, and physical characteristics including the energy efficiency of the residence. A semi-log hedonic equation is estimated using both robust and pooled OLS regressions as follows:

[10] Stata/IC Version 13.1 Revision 9

$$Ln(price_i) = \alpha + \beta X_i + \gamma_j A_j + \delta_k Q_k + \varphi P_i + \varepsilon_i \quad (4.1)$$

In Eq. 4.1 the natural log of the transaction price of home i in 2015 dollars is the dependent variable. α is a constant term, X_i is a vector of house characteristics for home i, and ε_i is a random disturbance term. A set of indicator variables indicating the Multiple Listing Service (MLS) area number are included to control for spatial effects such as differences in the quality of public amenities and school districts. A_j takes a value of one if home i is located in MLS area number j and zero otherwise. Indicator variables for the year-quarter (Q_k) in which the transaction took place are included to control for changes in economic and market conditions over the study period. Q_k has a value of one if home i was sold in year-quarter k and zero otherwise. P_i is the energy efficiency rating of home i in points. $\alpha, \beta, \gamma, \delta$ and φ are estimated coefficients. The parameter of interest is φ which measures the average percentage increase in the price premium associated with a one point increase in the energy efficiency points assigned to a home during an energy audit.

$$Ln(price_i) = \alpha + \beta X_i + \gamma_j A_j + \delta_k Q_k + \psi_m R_m + \varepsilon_i \quad (4.2)$$

In Eq(4.2) , also estimated using robust and pooled OLS regressions, the energy efficiency rating of the home is measured by its energy efficiency rating level instead of points. R_m is a set of indicator variables for the 1 Star through 6 Star energy efficiency rating level of home i at the time of the sale. The parameter of interest in Eq. 4.2 is ψ_m which measures the average price premium associated with an energy efficiency rating level. The equations are estimated separately for the Anchorage and Fairbanks residential real estate markets.

4.5 Data

Data on single-family home sales from 2008 through 2015 for both the Anchorage and Fairbanks markets were provided by the Alaska MLS. The data include the selling date and price of each home. The data also include the square footage of the home, the number of bedrooms and bathrooms, the car capacity of the garage, the age of the home, and the acreage of the property parcel. Information on whether the property has a heated garage is included in the data for Fairbanks[11] but not for Anchorage. Any property that did not include a transaction price was removed from the dataset.

Data on the energy ratings of homes are from the Cold Climate Housing Research Center (CCHRC) which manages the Alaska Retrofit Information System database on behalf of the AHFC. The data include the addresses of the homes and their energy ratings. The addresses in the CCHRC dataset were matched to addresses in the MLS dataset. All of the properties in this dataset have an as-is energy rating. Homes that completed the Weatherization program or the Rebate program have an as-is and post-improvement energy rating. If a home sold after it completed the Weatherization program or the Rebate program, the home was assigned its post-improvement rating. If a home sold before it completed the Weatherization program or the Rebate program or if the home never received a post-improvement rating, the home was assigned its as-is rating.

Assigning the as-is rating to homes that sold before the date of their as-is audit is based on the assumption that the energy efficiency of the home did not significantly change between

[11] Because of the damage to an engine caused by repeated stars in extremely cold winter temperatures, Fairbanks automobile owners must install engine block and oil pan heaters in their automobiles and plug them in several hours before starting them. Parking in a heated garage prevents the need to plug in one's car while at home and can save the homeowner money on their electric bill.

the date of the home sale and the date of the as-is energy audit. All else constant, the energy efficiency of a home is unlikely to degrade significantly over eight year period under consideration. Assigning the as-is rating to homes that sold before the date of their as-is audit also requires the assumption that homeowners did not make significant energy efficiency improvements before they applied for the Weatherization or Rebate program. It seems unlikely that a homeowner would pay out-of-pocket to make significant energy efficiency retrofits to their home before applying to a well-advertised, publicly-funded program which provided financial assistance for home energy efficiency retrofits. See Figure 4.4 for the distribution of energy efficiency ratings of homes in the Anchorage and Fairbanks samples.

There are a total of 4,211 homes in the Anchorage sample. Of these homes, 2,647 (62.9%) sold before the date of their as-is audit, and these homes were assigned their as-is energy rating. Another 1,564 (37.1%) homes sold after they underwent a post-improvement energy efficiency audit, and these homes were assigned their post-retrofit energy rating. Of the homes that sold after completing an energy efficiency retrofit, 93 (6%) were Weatherization participants and 1,471 (94%) were Rebate participants.

There are a total of 1,371 homes in the Fairbanks sample of which 925 (67.5%) sold before the date of their as-is audit and were assigned their as-is energy rating. The remaining 446 (32.5%) homes sold after the date of their post-improvement energy efficiency audit and were assigned their post-improvement rating. Of these 446 homes, 137 (31%) participated in the Weatherization program and 309 (69%) participated in the Rebate program.

Table 4.2 displays the distribution of housing transactions by year, energy rating, and decade of construction for the Anchorage and Fairbanks samples. As mentioned earlier, relatively few homes have energy ratings at either end of the energy rating scale in the Anchorage and Fairbanks samples. The average energy rating for homes in the Anchorage and Fairbanks samples are 3.35 Stars and 3.57 Stars, respectively, which is slightly higher than the overall average energy rating of 3 Stars for Anchorage and Fairbanks homes in the AkWarm database. The spatial distribution of housing transactions by their MLS area are displayed in Table 4.3, and the mean value of homes by their energy rating are displayed in Table 4.4.

The summary statistics for the Anchorage sample are displayed in Table 4.5. In the Anchorage sample, the mean price of a home is $347,451 and mean size of a home is 2,070 square feet. Table 4.6 displays the summary statistics for the Fairbanks sample. In the Fairbanks sample the mean price of a home is $221,985 and the mean size of a home is 1,852 square feet. On average, Anchorage homes sell for more than $125,000 more than Fairbanks single-family residences and are more than 200 square feet larger.

4.6 Results

4.6.1 Anchorage

The results of models estimated with the Anchorage sample are presented in Table 4.7. The first column reports the results for Eq. 4.1 estimated with a robust estimator. The parameter estimate for *Points* is positive and statistically significant at the one percent level. For each additional energy-rating point assigned to a home by an energy auditor, the value of the home increases by 0.3%[12]. At the mean transaction price of $347,451 in the sample for a single-family home in Anchorage, the price premium associated with an additional energy-rating point is $1,042. All

[12] Because of the model's log-level functional form, the transformation of $100 * \beta$ is used for the interpretation of the coefficients for continuous variables (Wooldridge, 2006). However, the transformation of $100 * [\exp(\beta) - 1]$ is used for the interpretation of the estimated coefficients of indicator variables (Halvorsen and Palmquist, 1980).

parameter estimates for home characteristics in this specification are statistically significant at the 5% level and have signs in the expected direction. The model explains approximately 64% percent of the variation in the selling prices of single-family homes in the Anchorage market.

The results of Eq. 4.1, estimated with OLS are reported in column three of Table 4.7. In this specification, the price premium associated with an additional energy rating-point is 0.4% ($1,390). In this specification, the parameter estimates for home characteristics are also statistically significant and in the expected direction. The model explains approximately 77% percent of the variation in single-family home sale prices in the Anchorage market. While most of the coefficients for Eq. 4.1 estimated with both the robust and OLS estimators are similar, the difference between the estimated coefficients for the *Points* variable is more substantial than it may initially appear because energy efficiency points are measured on a 0 to 100+ scale. Thus, for the robust regression, a 10 point increase in a home's energy efficiency rating equates to a $10,420 price increase for the average priced home in the sample, whereas for the OLS regression, a 10 point increase equates to a $13,900 price increase.

The results of Eq. 4.2 with the energy efficiency ratings of homes broken out into levels are presented in columns two and four of Table 4.7. Homes with an energy rating of 3 Stars are used as the base group because the 3 Stars is the average energy rating of the housing stock in Anchorage. The model column two is estimated with a robust estimator. Compared to homes with an energy rating of 3 Stars, homes with a 1 Star, 1 Star+, 2 Star, and 2 Star+ energy rating sell at a statistically significant price discount of 7.4%, 7.7%, 2.6%, and 1.3%, respectively. Compared to homes with an energy rating of 3 Stars, homes with a 3 Star+, 4 Star, 4 Star+, and 5 Star energy rating sell for a statistically significant price premium of 1.8%, 3.1%, 4.6%, and 6.0%, respectively. The price premium of 4.6% for homes with a 5 Star+ energy rating is not statically significant. The lack of significance for the 5 Star+ parameter estimate and smaller price premium for 5 Star+ homes compared to 5 Star rated homes is likely due to both the small number of observations and the wide range in transaction prices for the observations in the sample with a 5 Star+ energy rating. Parameter estimates for house characteristics are all significant at the 5% level and have signs in the expected direction. The model explains 64% of variation in home prices in the Anchorage sample.

The results of Eq. 4.2 estimated with OLS are presented in column 4 of Table 4.7. In this specification, compared to homes with a 3 Star rating, homes with 1 Star, Star+, 2 Star, and 2 Star+ homes sell for a price discount of 17.1%, 8.5%, 4.3%, and 1.7%, whereas homes with 3 Star+, 4 Star, 4 Star+, and 5 Star energy ratings sell for a statistically significant price premium of 1.9%, 4.4%, 6.0%, and 7.5%, respectively. The 5.8% price premium associated with 5+ Star home is not statistically significant. Again, the parameter estimates for house characteristics are significant at the 5% level and have signs in the expected direction. The model explains 77% of the variation in single-family home prices in the Anchorage housing market. Although the parameter estimates for most of the house characteristics are similar in both the robust and OLS specifications, the parameter estimates for the 1 Star energy efficiency rating are substantially different indicating that outliers in the 1 Star category may have undue influence on the parameter estimate in OLS specification.

4.6.2 Fairbanks

The results for Eq. 4.1 and Eq. 4.2 estimated with the Fairbanks sample are displayed in Table 4.8. The results of Eq. 4.1 estimated with a robust estimator are reported in column one. All parameter estimates are statistically significant and in have signs in the expected direction.

The results indicate that for each additional energy-rating point, the selling price of a home in Fairbanks increases by 0.5%. At the mean home price in the sample of $221,985, the average price premium associated with a one point increase equals $1,110. The model explains approximately 55% of the variation in single-family home prices in the Fairbanks market. The results of Eq. 4.1 estimated with OLS are reported in column three of Table 4.8. In this specification, a one point increase in the energy rating of a home is associated with a statistically significant price premium of 0.8% ($1,776). The coefficient for *Bedroom* is no longer statistically significant in the OLS regression. However, all other coefficients are statistically significant and have signs in the expected direction. The model explains 60% of the variation in single-family home prices in the Fairbanks market. Notably, the coefficient for the *Heated Garage* variable is substantially different between the robust and OLS regressions. For the robust regression, a heated garage adds 8.8% to the value of a home, whereas for the OLS regression, a heated garage adds 17.7%.

Columns two and four of Table 4.8 report the results of Eq. 4.2 estimated with energy rating broken out into levels. The results in column two present the empirical results of Eq. 4.2 estimated with a robust estimator. Homes with a 3 Star energy rating are used as the base group because 3 Stars is the average energy efficiency rating of Fairbanks homes in the AkWarm database. The results indicate that in Fairbanks, relative to a home with a 3 Star energy rating, homes with a 1 Star, 1 Star+, 2 Star, and 2 Star+ energy ratings sell at a discount of 13.3%, 12.2%, 12.4%, and 5.0%, respectively. Compared to homes with a 3 Star energy rating, homes in Fairbanks with 4 Star, 4 Star+, 5 Star, and 5 Star+ energy ratings sell for a price premium of 6.9%, 9.0%, 17.5%, and 12.7%, respectively. The parameter estimate for 5 Star+ energy rating is lower than the parameter estimate for 5 Star energy rating. As in the Anchorage sample, there are few observations in the Fairbanks sample with a 5 Star+ energy rating and there is a wide range in the transaction values for these observations. The 1.9% price premium associated with a 3 Star+ home is not statistically different compared to a 3 Star home. The model explains 56% of the variation in Fairbanks home prices. All other parameter estimates for house characteristics are statistically significant and have signs in the expected direction.

The results of Eq. 4.2 estimated with the OLS are reported in column 4 of Table 4.8. In Fairbanks, relative to 3 Star homes, homes with a 1 Star, 1 Star+, 2 Star, and 2 Star+ sell for a price discount of 13.8%, 32.6%, 16.18%, and 14.3%, respectively. Homes with 4 Star, 4 Star+, 5 Star, and 5 Star+ sell for price premiums of 11.4%, 13.3%, 29.2%, and, 22.8%, respectively when compared to homes with a 3 Star energy rating. The price of 3 Star+ homes is not significantly different than homes with a 3 Star rating. The model explains 61% of the variation in single-family home prices in the Fairbanks market. In the OLS regression the estimated coefficient for *Bedroom* is not significant. All other coefficients for house characteristics are significant and have signs in the expected direction. Additionally, in the OLS regression the estimated coefficient for a *Heated Garage* is roughly double the estimated coefficient in the robust regression.

Robust regression reduces the influence of outliers and high leverage data points on parameter estimates by first dropping the most influential points and then down-weighting observations with large absolute residuals. No observations were dropped from the robust regressions meaning that no observation had a Cook's distance greater than one. Nevertheless, the disparity between the estimated coefficients for the OLS and robust regressions suggest that outliers and high leverage data points are influencing the OLS regression coefficients. For both the Anchorage and Fairbanks samples, the estimated parameters for the energy efficiency ratings in the robust regressions are more in line with expectations than the parameter estimates in the OLS regressions.

4.7 Conclusion and Policy Implications

This study uses a hedonic pricing framework to examine the effect of energy efficiency ratings on home prices in two Alaska housing markets. The results indicate that homes with above-average energy efficiency ratings command a price premium between 1.8% and 6.0% in the Anchorage market and between 6.9% and 17.5% in the Fairbanks market suggesting that homebuyers in these markets place a positive value on energy efficiency. It is possible that homes with high energy efficiency ratings also have unobserved desirable characteristics driving the price premium. Although it is not possible to control for all quality differences between homes with different energy efficiency ratings, various hedonic characteristics of properties were controlled for in the regression analyses.

The results of this study are in accordance with the results of other studies investigating energy efficiency and the transaction prices in residential real estate markets. The results of several previous studies investigating the impact of residential energy efficiency on transaction prices in U.S. housing markets show that energy efficient properties command between a 2% and 9% price premium compared to similar properties with lower energy efficiency ratings (Bond and Devine, 2016; Kahn and Kok, 2014,Walls et al., 2016). In European housing markets, energy efficient properties command price premiums between 1.5% and 25% (Davis et al., 2015; de Ayala, 2016; Fuerst et al., 2015; Fuerst et al., 2016; Hyland et al., 2013). The results of studies on the Singapore housing market indicate that energy efficient properties sell for a price premium between 4% and 28% compared to less energy efficient properties (Addae-Dapaah and Chieh, 2011; Deng et al., 2012).

Given Alaska's cold climate and high energy prices, it is unsurprising that homebuyers are willing to pay a price premium for energy efficient homes in Alaska property markets. Because Anchorage and Fairbanks households dedicate a large portion of their residential energy use to space heating, improving the energy efficiency of these homes may lead to potentially significant savings on household energy costs. The price premium paid for energy efficient homes is higher in the Fairbanks market than in the Anchorage market. Fairbanks has both a colder climate and higher average annual home energy costs than Anchorage. Therefore, the potential energy savings associated with living in an energy efficient property are likely greater in Fairbanks in than in Anchorage.

Improving the energy efficiency rating of one's home is a prudent investment if the costs required to make the improvements are less than the price premium received for energy efficient properties or if potential savings exceed the initial costs of the improvements. This is the first study to investigate the relationship between the energy efficiency ratings and residential transaction prices in Alaska housing markets. Future studies should focus on the cost of improving the energy efficiency ratings of homes and the energy savings resulting from these investments. This would allow researchers to determine whether energy efficiency investments are recouped through energy savings and would also allow researchers to determine if energy efficiency investments are fully capitalized into the transaction prices of homes.

Buyers who purchase energy efficient homes in Anchorage and Fairbanks benefit financially in three main ways. First, the AHFC offers reduced interest rates on mortgages for homes meeting energy efficiency criteria through the Energy Efficiency Interest Rate Reduction program (AHFC, 2016). Secondly, energy efficient properties require less energy to maintain a comfortable indoor temperature leading to lower household energy costs compared to less energy efficient properties. Lastly, buyers of energy efficient homes benefit when they resell their homes because energy efficient homes command price premiums in both markets.

Residential energy ratings reduce information asymmetry between buyers and sellers in the housing market by providing a means of signaling the energy efficiency of properties. However, not all homes in Alaska have energy ratings because not all homes have undergone energy efficiency audits. Homes in the Anchorage and Fairbanks samples received energy ratings after undergoing energy audits that were either totally or partially funded with public dollars. Continued state funding for residential energy audits is beneficial because energy efficiency ratings reduce information asymmetry in the housing market and, the data collected during energy efficiency audits provides useful information regarding the overall condition of the housing stock throughout Alaska which can be used to inform state housing policy.

4.8 References

ACRC (Alaska Climate Research Center), 2016. Climate normal. http://climate.gi.alaska.edu/ClimTrends/Change/TempChange.html (accessed 19.12.2016).

Addae-Dapaah, K., Chieh, S. J., 2011. Green mark certification: Does the market understand? Journal of Sustainable Real Estate 3(1), 162-191.

AHFC (Alaska Housing Finance Corporation), 2013a. Home energy rebate program guidelines. https://www.ahfc.us/files/1913/7401/5545/HER_program_guidelines.pdf (accessed 23.11.2016)

AHFC (Alaska Housing Finance Corporation), 2013b. Alaska Housing Finance Corporation Alaska energy rater manual: Revision 2. https://www.ahfc.us/files/8814/0296/1045/energy_rater_manual_090113.pdf (accessed 10.11.2016).

AHFC (Alaska Housing Finance Corporation), 2014. Alaska Housing Assessment. https://www.ahfc.us/efficiency/research-information-center/housing-assessment/ (accessed 03.04 2016)

AHFC (Alaska Housing Finance Corporation), 2016. Energy efficiency interest rate reduction. https://www.ahfc.us/efficiency/energy-programs/energy-efficiency-rate-reduction/ (accessed 06.01.2017).

Alaska DCCED (Department of Commerce, Community, and Economic Development), 2016. Alaska fuel price report: Current community conditions.

https://www.commerce.alaska.gov/web/Portals/4/pub/Fuel_Price_Report_July_2016.pdf (accessed 07.02.2017)

Alaska Journal of Commerce, 2008. Weatherization, home energy funds becoming available. http://www.alaskajournal.com/community/2008-05-25/weatherization-home-energy-funds-becoming-available#.V-QSM6L-R4N (accessed 18.09.2016).

Baltensperger, A., 2016. Map of Alaska with the Municipality of Anchorage shaded in blue and the FNSB shaded in yellow. ArcGIS.

Bloom, B., Nobel, M.C., Nobe, M. 2011. Valuing Green Home Designs: A study of energy star homes. Journal of Sustainable Real Estate 3(1), 109-126.

Boardman, B., 2010. Fixing fuel poverty: Challenges and solutions. Earthscan, New York.

Bond, S.A., Devine, A., 2016. Certification matters: Is green talk cheap talk? Journal of Real Estate Finance and Economics 52, 117-140.

Brehmer, E., 2016. Budget deficit hits state energy programs, rebates cut. Alaska Journal of Commerce. http://www.alaskajournal.com/2016-03-02/budget-deficit-hits-state-energy-programs-rebates-cut#.V-czn6L-R4O (accessed 01.09.2016)

Cerin, P., Hassel, L.G., Semenova, N., 2014. Energy performance and housing prices. Sustainable Development 22, 404-419.

Davis P.T., McCord, J., McCord, M.J., Haran, M., 2015. Modeling the effect of energy performance certificate rating on property value in the Belfast housing market. International Journal of Housing Markets and Analysis 8(3), 292-317.

de Ayala, A., Galarraga I., Spadaro, J.V., 2016. The price of energy efficiency in the Spanish housing market. Energy Policy 94, 16-24.

Deng, Y., Li, Z., Quigley, J.M., 2012. Economic returns to energy-efficient investments in the housing market: Evidence from Singapore. Regional Science and Urban Economics 42, 506-515.

EIA (Energy Information Administration), 2013. Heating and cooling no longer majority of U.S. home energy use. http://www.eia.gov/todayinenergy/detail.php?id=10271 (accessed 16.12.2016).

EIA (Energy Information Administration), 2015. Energy units and calculators explained: Degree-days. http://www.eia.gov/energyexplained/index.cfm?page=about_degree_days (accessed 11.03. 2016).

EIA (Energy Information Administration), 2016. Alaska state profile and energy estimates. http://www.eia.gov/state/?sid=AK#tabs-5 (accessed 03.11.2016).

EIA (Energy Information Administration), 2017. Natural gas: Alaska price of natural gas delivered to residential customers. https://www.eia.gov/dnav/ng/hist/n3010ak3A.htm (accessed 07.02.2017).

Eichholtz, P., Kok, N., Quigley, J.M., 2010. Doing well by doing good? Green office buildings. American Economic Review 100 (5), 2492-2509.

Energy Star, 2016. History of Energy Star guidelines for new homes. https://www.energystar.gov/index.cfm?c=new_homes.nh_history (accessed 15.12.2016)

EUR-Lex, 2007. Energy efficiency: Energy performance of buildings. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al27042 (accessed 24.06.2016).

Fuerst, F., McAllister, P., 2011. The impact of energy performance certificates on the rental and capital values of commercial property assets. Energy Policy 39 (10), 6608-6614.

Fuerst, F., Oikarinen, E., Harjunen, O., 2016. Green clientele effects in the Helsinki metropolitan area housing market, City of Helsinki Urban Facts Working Papers 2016:3.

Fuerst, F., McAllister, P., Nanda, A., Wyatt, P., 2015. Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transactions in England. Energy Economics 48, 145-156.

Goldsmith, S., Pathan, S., Wiltse, N., 2012. Snapshot: the home energy rebate program. Institute of Social and Economic Research, University of Alaska Anchorage. http://cchrc.org/docs/snapshots/HERP_snapshot.pdf (accessed 13.11.2016).

GVEA (Golden Valley Electric Association), 2017. Rates. http://www.gvea.com/rates/rates (accessed 07.02.2017).

Halvorsen, R., Palmquist, R., 1980. The interpretation of dummy variables in semilogarithmic equations. The American Economic Review 70 (3), 474-475.

Hyland, M., Lyons, R.C., Lyons, S., 2013. The value of domestic building energy efficiency: Evidence from Ireland. Energy Economics 40, 943-952.

Indiana University Bloomington, 2016. Green building background. Retrieved from http://sustain.indiana.edu/programs/green-building/background.php (Accessed September 23, 2016)

Information Insights, 2009. Alaska housing assessment: Part I and II. http://www.cchrc.org/docs/reports/TR_2009_02_2009_AK_Housing_Assessment_Final.pdf (accessed 01.09.2016).

Kahn, M.E., Kok, N., 2014. The capitalization of green labels in the California housing market. Regional and Urban Economics 47 (2014) 25-34.

Mandell, S., Wilhelmsson, M., 2011. Willingness to pay for sustainable housing. Journal of Housing Research 20 (1), 35-51.

ML&P (Municipal Light & Power), 2017. Residential rates. https://www.mlandp.com/Customers/Rates/Residential-Rates (accessed 07.01.2017).

Reichardt, A., Ruerst, F., Rottke, N.B., Zietz, J., 2012. Sustainable building certification and the rent premium: a panel data approach. Journal of Real Estate Research 34 (1), 99-126.

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy 82 (1), 34-55.

Sivak, M., 2013. Air conditioning versus heating: climate control is more energy demanding in Minneapolis than Miami. Environmental Research Letters 8 (1), 1-4.

Stata, 2013. Stata User's Guide: rreg-robust regression. http://www.stata.com/manuals13/rrreg.pdf (accessed 22.11.2016).

U.S. Census Bureau, 2015. QuickFacts: Fairbanks North Star Borough, Alaska. http://www.census.gov/quickfacts/table/PST045215/02090 (accessed 23.12. 2016).

U.S. Census Bureau, 2016. QuickFacts: Anchorage Municipality, Alaska (County). http://www.census.gov/quickfacts/table/EDU635214/02020 (accessed 04.12. 2016).

Verardi, V., Croux, C., 2009. Robust regression in Stata. The Stata Journal 9 (3), 439-453.

Walls, M., Palmer, K., Gerarden, T., Bak, X., 2016. Is energy efficiency capitalized into home prices? Evidence from three U.S. cities. Resources for the Future, working paper.

Waterman, S. 2017, January 30. Alaska Housing Finance Cooperation State Energy Program Manager, e-mail message to author.

Wiley, J.A., Benefield, J.D., Johnson, K.H., 2010. Green designs and the market for commercial office space. Journal of Real Estate Finance and Economics 41, 228-243.

Wooldridge, J., 2006. Introductory econometrics: A modern approach. Thompson South-Western, Mason OH.

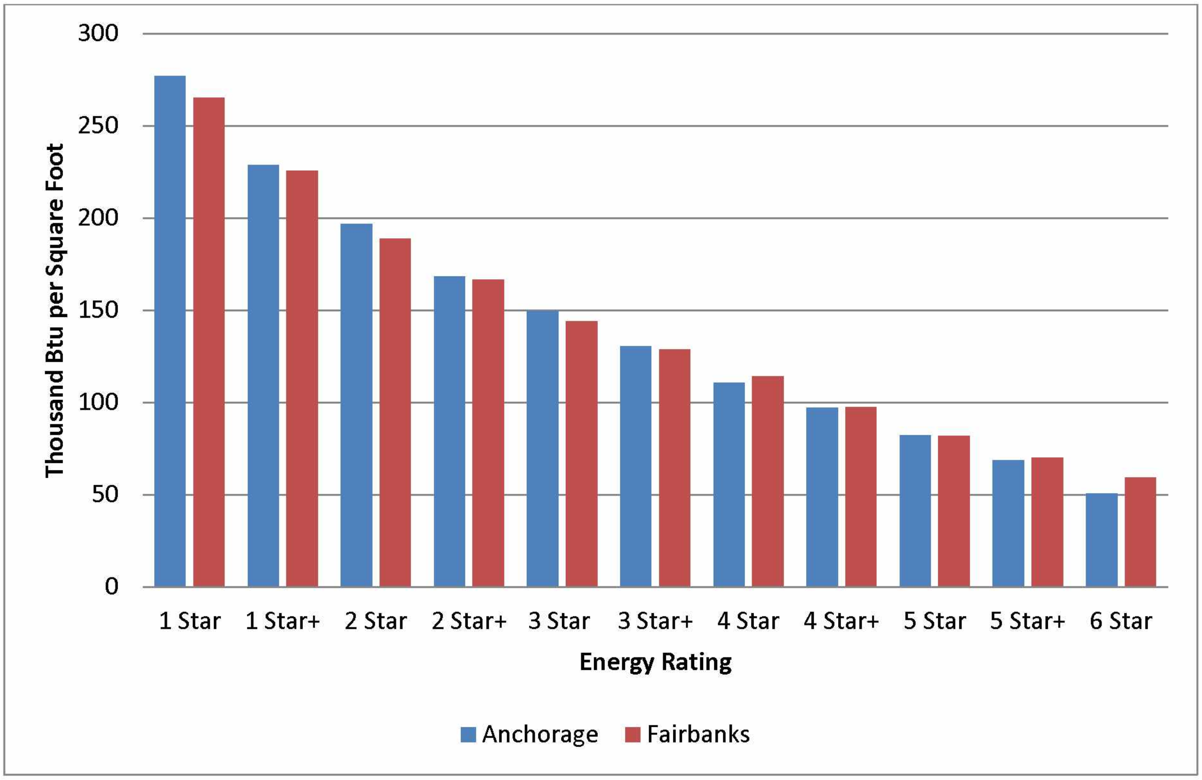

Figure 4.1. Average household energy consumption by energy rating

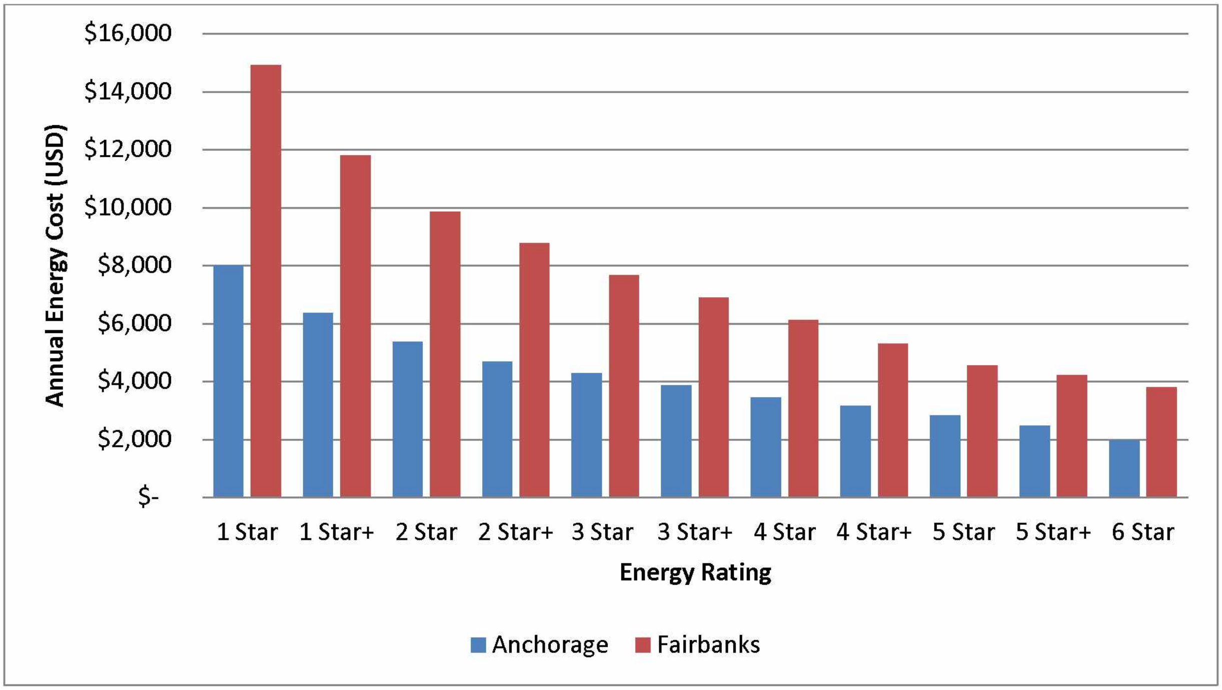

Figure 4.2. Estimated annual household energy cost by energy efficiency rating

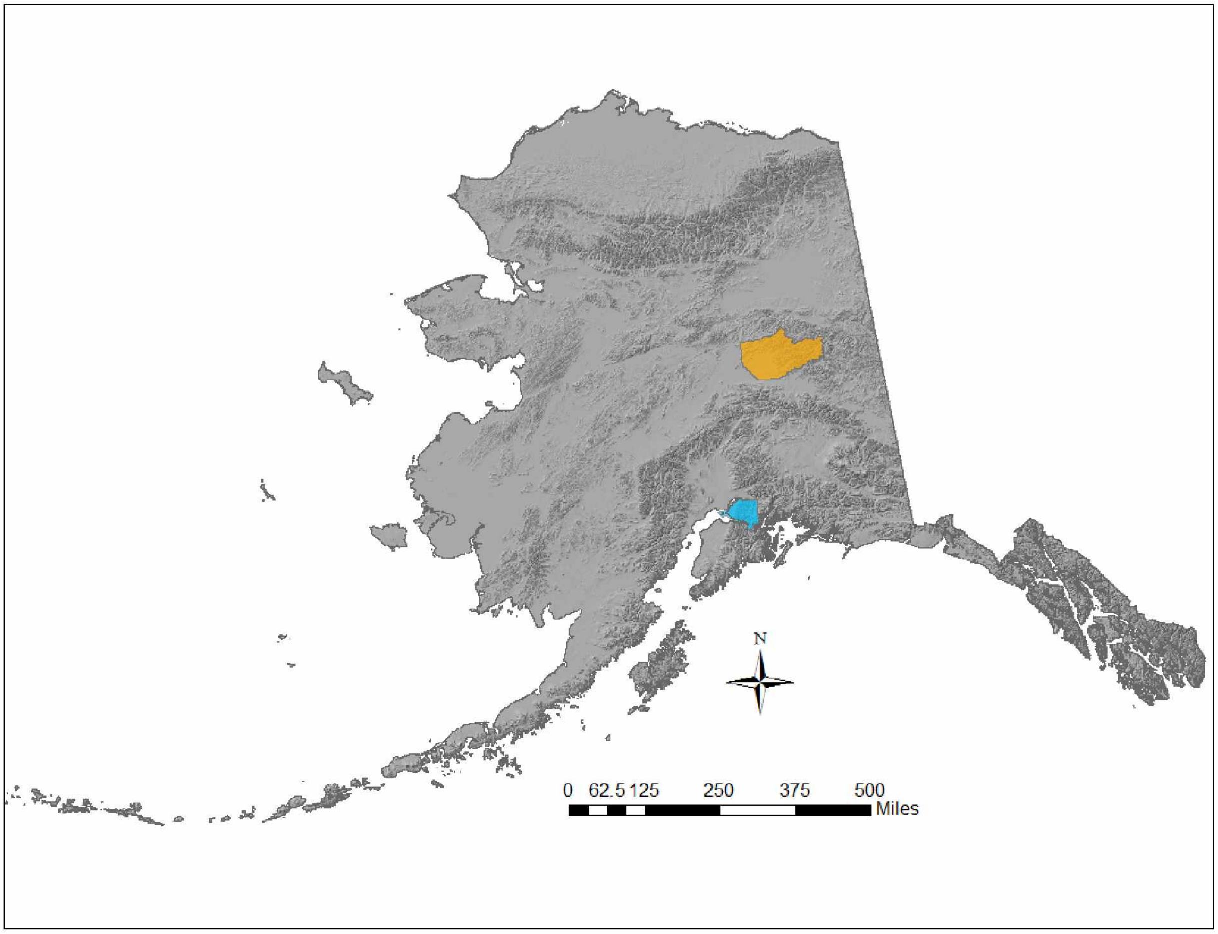

Figure 4.3. Map of Alaska with the Municipality of Anchorage shaded in blue and the FNSB shaded in yellow (Baltensperger, 2016)

Table 4.1. Point values for energy ratings

Points	Ratings
0-39	1 Star
40-49	1 Star +
50-59	2 Star
60-67	2 Star +
68-72	3 Star
73-77	3 Star +
78-82	4 Star
83-88	4 Star +
89-91	5 Star
92-94	5 Star +
95-100+	6 Star

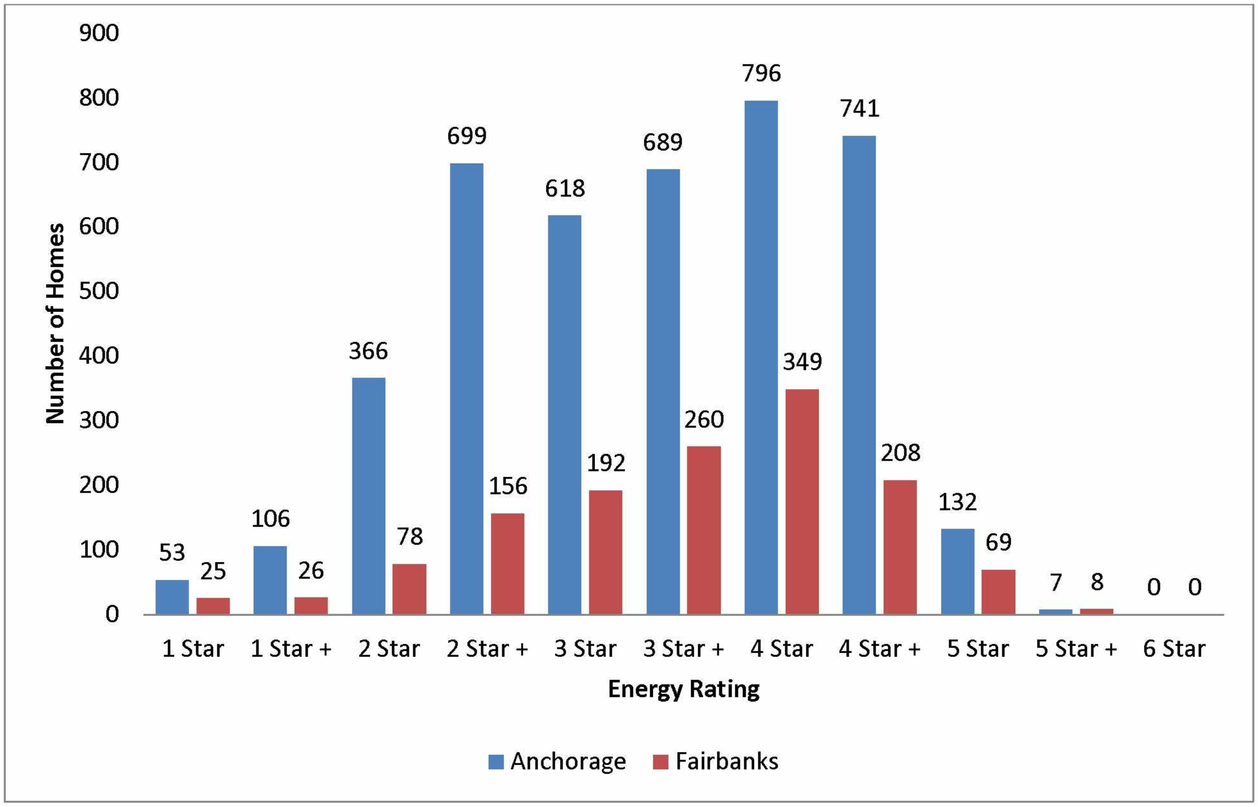

Figure 4.4. Distribution of housing transactions by energy rating in the Anchorage and Fairbanks samples

Table 4.2. Distributions of housing transactions

	Anchorage		Fairbanks	
A. Distribution of housing transactions by year				
Year	Frequency	Percentage	Frequency	Percentage
2008	569	14%	181	13%
2009	544	13%	216	16%
2010	505	12%	148	11%
2011	541	13%	158	12%
2012	603	14%	172	13%
2013	617	15%	170	12%
2014	422	10%	170	12%
2015	406	10%	156	11%
Total	4,207	100%	1,371	100%
B. Distribution of housing transactions by energy rating				
Rating	Frequency	Percent	Frequency	Percentage
1 Star	53	1%	25	2%
1 Star +	106	3%	26	2%
2 Star	366	9%	78	6%
2 Star +	699	17%	156	11%
3 Star	618	15%	192	14%
3 Star +	689	16%	260	19%
4 Star	796	19%	349	25%
4 Star +	741	18%	208	15%
5 Star	132	3%	69	5%
5 Star +	7	0%	8	1%
6 Star	0	0%	0	0%
Total	4,207	100%	1,371	100%
C. Distribution of housing transactions by decade of construction				
Year	Frequency	Percent	Frequency	Percentage
Pre-1950	25	1%	33	2%
1950-1959	260	6%	106	8%
1960-1969	526	13%	117	9%
1970-1979	1394	33%	356	26%
1980-1989	1380	33%	467	34%
1990-1999	465	11%	126	9%
2000-2009	153	4%	164	12%
Post-2009	4	0%	2	0%
Total	4,207	100%	1,371	100%

Table 4.3. Distribution of housing transactions by MLS area

Anchorage MLS Area	Frequency	Percentage
Abbot Road-Dearmoun Road	699	17%
Boniface Parkway to Muldoon Road	579	14%
Chugiak/Peters Creek	123	3%
Dearmoun Road-Potter Marsh	171	4%
Dimond South	510	12%
Downtown	33	1%
Eagle River	487	12%
East Tudor Road-Abbot Road	395	9%
Girdwood-Turnagain Arm	8	0%
Post Road-Glenn Highway	17	0%
Seward Highway to Boniface Parkway	385	9%
Spendard	279	7%
West Tudor Road-Diamond Boulevard	521	12%
Total	4,207	100%
Fairbanks MLS Area	Frequency	Percentage
Badger and Rural North Pole	394	29%
Chena Hot Springs Road	39	3%
City of North Pole	36	3%
East Fairbanks	129	9%
East Rural Fairbanks	83	6%
North Fairbanks	197	14%
Northwest Rural Fairbanks	91	7%
Rural Fairbanks	153	11%
Salcha	6	0%
South Fairbanks	63	5%
Southwest Rural Fairbanks	80	6%
West Fairbanks	100	7%
Total	1,371	100%

Table 4.4. Mean value of homes by energy rating (USD)

	Anchorage			Fairbanks		
Rating	Mean	Std. Dev.	Frequency	Mean	Std. Dev.	Frequency
1 Star	251,604	111,676	53	152,396	58,936	25
1 Star +	260,081	67,870	106	139,912	65,423	26
2 Star	294,771	86,676	366	157,991	55,955	78
2 Star +	324,920	100,944	699	175,740	68,720	156
3 Star	323,915	90,233	618	205,249	68,554	192
3 Star +	357,182	128,274	689	212,954	67,903	260
4 Star	374,214	115,033	796	237,211	67,193	349
4 Star +	388,401	132,960	741	266,260	80,299	208
5 Star	389,685	162,460	132	313,799	93,395	69
5 Star +	346,198	106,882	7	319,929	104,128	8
6 Star	N/A	N/A	0	N/A	N/A	0

Table 4.5. Anchorage summary statistics

Variable	Definition	Mean	Std. Dev.	Min.	Max.
Price	Transaction price of the property	347,451	119,019	81,394	1,651,959
lnRprice	Natural log of transaction price	12.71	0.31	11.31	14.32
Points	Energy efficiency point rating	72.98	11.33	0.00	93.9
1 Star	Indicator variable for a 1 Star energy rating	0.01	0.11	0.00	1.00
1 Star +	Indicator variable for a 1 Star + energy rating	0.03	0.16	0.00	1.00
2 Star	Indicator variable for a 2 Star energy rating	0.09	0.28	0.00	1.00
2 Star +	Indicator variable for a 2 Star + energy rating	0.17	0.37	0.00	1.00
3 Star	Indicator variable for a 3 Star energy rating	0.15	0.35	0.00	1.00
3 Star +	Indicator variable for a 3 Star + energy rating	0.16	0.37	0.00	1.00
4 Star	Indicator variable for a 4 Star energy rating	0.19	0.39	0.00	1.00
4 Star +	Indicator variable for a 4 Star + energy rating	0.18	0.38	0.00	1.00
5 Star	Indicator variable for a 5 Star energy rating	0.03	0.17	0.00	1.00
5 Star +	Indicator variable for a 5 Star + energy rating	0.00	0.04	0.00	1.00
6 Star	Indicator variable for a 6 Star energy rating	0.00	0.00	0.00	0.00
Square feet	Square footage of the residence	2,070	779	600	11,455
Bedrooms	Number of bedrooms	3.43	0.74	1.00	11.00
Bathrooms	Number of bathrooms	2.26	0.71	0.75	13.00
Garage Capacity	Number of cars a garage can hold	1.72	0.85	0.00	7.00
Age	Age of property at sale	37.86	11.55	4.00	75.00
Acres	Acreage of the property	0.35	0.44	0.00	6.30

Table 4.6. Fairbanks summary statistics

Variable	Definition	Mean	Std. Dev.	Min.	Max.
Price	Transaction price of the property	221,985	81,058	16,543	700,731
lnRprice	Natural log of the transaction price of the property	12.23	0.43	9.71	13.46
Points	Energy efficiency point rating	74.54	11.56	0.00	93.8
1 Star	Indicator variable for a 1 Star energy rating	0.02	0.13	0.00	1.00
1 Star +	Indicator variable for a 1 Star + energy rating	0.02	0.14	0.00	1.00
2 Star	Indicator variable for a 2 Star energy rating	0.06	0.23	0.00	1.00
2 Star +	Indicator variable for a 2 Star + energy rating	0.11	0.32	0.00	1.00
3 Star	Indicator variable for a 3 Star energy rating	0.14	0.35	0.00	1.00
3 Star +	Indicator variable for a 3 Star + energy rating	0.19	0.39	0.00	1.00
4 Star	Indicator variable for a 4 Star energy rating	0.25	0.44	0.00	1.00
4 Star +	Indicator variable for a 4 Star + energy rating	0.15	0.36	0.00	1.00
5 Star	Indicator variable for a 5 Star energy rating	0.05	0.29	0.00	1.00
5 Star +	Indicator variable for a 5 Star + energy rating	0.01	0.08	0.00	1.00
6 Star	Indicator variable for a 6 Star energy rating	0.00	0.00	0.00	0.00
Square feet	Square footage of the residence	1,852	711	450	5,474
Bedrooms	Number of bedrooms	3.08	0.88	1.00	6.00
Bathrooms	Number of bathrooms	2.06	0.76	1.00	5.00
Garage capacity	Number of cars a garage can hold	1.56	0.96	0.00	6.00
Heated garage	Indicator variable for heated garage	0.74	0.44	0.00	1.00
Age	Age of property at time of sale in years	31.11	14.90	1.00	89.00
Acres	Acreage of the property	1.35	2.11	0.00	40.00

Table 4.7. Anchorage regression results

Dependent variable: Ln(Sale Price)	Robust coefficients		OLS coefficients	
	Model 1:	Model 2:	Model 3:	Model 4:
1 Star		**-0.071*** **		**-0.158*** **
		(0.017)		**(0.037)**
1 Star +		**-0.074*** **		**-0.082*** **
		(0.013)		**(0.018)**
2 Star		**-0.026*** **		**-0.042*** **
		(0.008)		**(0.011)**
2 Star +		**-0.013* **		**-0.017* **
		(0.007)		**(0.009)**
3 Star		Holdout		Holdout
3 Star +		**0.018*** **		**0.019** **
		(0.007)		**(0.009)**
4 Star		**0.031*** **		**0.043*** **
		(0.007)		**(0.008)**
4 Star +		**0.045*** **		**0.058*** **
		(0.007)		**(0.009)**
5 Star		**0.058*** **		**0.072*** **
		(0.012)		**(0.012)**
5 Star +		0.045		0.056
		(0.045)		(0.044)
Points	**0.003*** **		**0.004*** **	
	(0.000)		**(0.000)**	
Square Feet (hundreds)	0.019***	0.019***	0.017***	0.017***
	(0.000)	(0.000)	(0.001)	(0.001)
Bedrooms	0.007**	0.008**	0.011**	0.012***
	(0.003)	(0.003)	(0.005)	(0.005)
Bathrooms	0.043***	0.043***	0.032**	0.033**
	(0.004)	(0.004)	(0.014)	(0.014)
Garage Capacity	0.075***	0.075***	0.085***	0.085***
	(0.003)	(0.003)	(0.005)	(0.005)
Age	-0.001***	-0.001***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Acres	0.095***	0.095***	0.097***	0.097***
	(0.005)	(0.005)	(0.011)	(0.011)
Constant	12.123***	12.301***	12.028***	12.278***
	(0.033)	(0.029)	(0.072)	(0.071)
Quarter FE	Yes	Yes	Yes	Yes
MLS Area Number FE	Yes	Yes	Yes	Yes
Observations	4,207	4,207	4,207	4,207

Table 4.7 Continued

R-squared	0.638†	0.638†	0.768	0.768
AIC	5,048†	5,052†	-4,049	-4,033
BIC	5,386†	5,444†	-3,726	-3,659

Notes: Standard errors are reported in parentheses. Heteroscedasticity robust standard errors are used for OLS regressions. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively. Fit indices calculated with UCLA Statistical Consulting's rregfit program are indicated by †.

Table 4.8. Fairbanks regression results

Dependent variable: Ln(Sale Price)	Robust coefficients		OLS coefficients	
	Model 1:	Model 2:	Model 3:	Model 4:
1 Star		**-0.125*** **		**-0.129***
		(0.033)		**(0.066)**
1 Star +		**-0.115*** **		**-0.282*** **
		(0.033)		**(0.082)**
2 Star		**-0.117*** **		**-0.150*** **
		(0.021)		**(0.047)**
2 Star +		**-0.049*** **		**-0.134*** **
		(0.017)		**(0.038)**
3 Star		Holdout		Holdout
3 Star +		0.019		0.024
		(0.015)		(0.029)
4 Star		**0.067*** **		**0.108*** **
		(0.014)		**(0.029)**
4 Star +		**0.086*** **		**0.125*** **
		(0.017)		**(0.033)**
5 Star		**0.161*** **		**0.256*** **
		(0.023)		**(0.035)**
5 Star +		**0.120** **		**0.205*** **
		(0.057)		**(0.058)**
Points	**0.005*** **		**0.008*** **	
	(0.000)		**(0.001)**	
Square Feet (hundreds)	0.020***	0.020***	0.019***	0.019***
	(0.001)	(0.001)	(0.002)	(0.002)
Bedrooms	0.029***	0.029***	0.016	0.018
	(0.006)	(0.006)	(0.014)	(0.014)
Bathrooms	0.028***	0.029***	0.055***	0.053***
	(0.008)	(0.008)	(0.014)	(0.014)
Garage Capacity	0.051***	0.052***	0.055***	0.056***
	(0.006)	(0.006)	(0.012)	(0.012)
Heated Garage	0.084***	0.081***	0.163***	0.156***
	(0.012)	(0.013)	(0.027)	(0.028)
Age	-0.004***	-0.004***	-0.004***	-0.003***
	(0.000)	(0.000)	(0.001)	(0.001)
Acres	0.010***	0.009***	0.020***	0.019***
	(0.002)	(0.002)	(0.006)	(0.006)
Constant	11.358***	11.733***	11.016***	11.577***
	(0.046)	(0.036)	(0.098)	(0.069)
Quarter FE	Yes	Yes	Yes	Yes
MLS Area Number FE	Yes	Yes	Yes	Yes

Table 4.8 continued

Observations	1,371	1,371	1,371	1,371
R-squared	.5503†	.5561†	0.595	0.608
AIC	2,008†	1,985†	428	399
BIC	2,299†	2,321†	694	707

Notes: Standard errors are reported in parentheses. Heteroscedasticity robust standard errors are used for OLS regressions. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively. Fit indices calculated with UCLA Statistical Consulting's rregfit program are indicated by †.

Chapter 5

Conclusions

In this chapter, three studies regarding the relationship between residential energy efficiency and transaction prices of single-family homes in Alaska real estate markets are summarized. Then the findings, contributions, and limitations of the studies are discussed, followed by recommendations for future research and a brief conclusion.

5.1 Summary of Chapters

The overarching purpose of this body of work is to examine the relationship between energy efficiency and the transaction prices of single-family homes in Alaska's Fairbanks and Anchorage residential real estate markets using the hedonic pricing framework. Residential energy efficiency is an important issue in Alaska because homeowners in many regions of the state face household energy costs that are far above the national average due to the combination of the state's cold climate and relatively high energy prices (AHFC, 2014; Information Insights, 2009). Improving the energy efficiency of the housing stock can reduce the amount of energy required to keep homes at a comfortable temperature thereby reducing household energy costs and CO_2 emissions (Boardman, 2010).

The impact of participating in the Alaska Home Energy Rebate (Rebate) program on residential property prices in the Fairbanks North Star Borough (Fairbanks) and Municipality of Anchorage (Anchorage) real estate markets was examined in the second and third chapters, respectively. The Rebate program was a state-funded residential energy efficiency program administered by the Alaska Housing Finance Corporation (AHFC) that was established by the state legislature in 2008 to incentivize investment in residential energy efficiency improvements

(Goldsmith et al., 2012). Through the Rebate program, homeowners could receive a rebate up to $10,000 for preapproved energy efficiency improvements made to their homes. Due to state budgetary shortfalls, the Rebate program was suspended in early 2016 (Brehmer, 2016). For both Fairbanks and Anchorage markets, the addresses of Rebate participants were matched with the addresses of properties in the Multiple Listing Service property sales database for the time period between 2008 and 2015.

Chapter 1 provided a general introduction and context for the research. The hedonic pricing framework was introduced and the research questions were listed, followed by a brief summary of each chapter.

Chapter 2 investigated the impact of participating in the Rebate program on transaction prices of single-family homes in the Fairbanks market from 2008 through 2015. Log-linear hedonic models were estimated with heteroscedasticity robust standard errors using both the full sample of single-family transactions and also using a subset of control properties matched to Rebate homes based on their observable attributes using propensity score matching. The full sample consisted of 6,094 observations and the propensity score matched (PSM) sample consisted of 1,100 observations. The results indicated that compared to similar homes that did not participate in the Rebate program in the Fairbanks market, homes that completed the Rebate program sold for a price premium of 15.5% when the model was estimated with the full sample and 15.1% when the model was estimated with the PSM sample.

Chapter 3 investigated the impact of participating in the Rebate program on single-family home prices in the Anchorage market from 2008 through 2015. Like the Fairbanks chapter, log-linear hedonic models with heteroscedasticity robust standard errors were estimated using both the full sample consisting of 26,642 observations and a PSM sample consisting of 4,947 observations. The results indicated that compared to similar homes that did not participate in the Rebate program in the Anchorage market, homes that completed the Rebate program sell for a price premium of 11% when the model was estimated with the full sample and 10% when the model was estimated with the PSM sample.

Because part of the price premium associated with participating in the Rebate program could possibly be attributed to differences between the initial values of homes of those that did and did not select into the Rebate program, a difference-in-differences (DiD) model was estimated for a subsample of 8,096 homes that sold at least twice over the study period. There were too few repeat sales in the Fairbanks sample to conduct a DiD analysis for the Fairbanks market. The use of a DiD model allows one to determine if there was a difference between the values of the homes of those who did and did not opt into the Rebate program before the homes underwent an energy efficiency retrofit. The results suggested that the homes of those who eventually selected into the Rebate program in the Anchorage market were, on average, worth 5% more at the time of their first sale before participating in the Rebate program than the homes of those that did not select into the program. After controlling for the differences in the first sale prices and the price appreciation trend between the first and second sales of homes, the results indicated that homes that sold after completing the Rebate program sold for a 5% premium over similar homes that did not complete the Rebate program in the Anchorage market.

Chapter 4 analyzed the relationship between the energy efficiency ratings and the transaction prices of single-family homes in the Anchorage and Fairbanks markets from 2008 through 2015. The sample was comprised of housing transactions for homes that eventually participated in either Rebate program or the Weatherization program, which provided energy efficiency upgrades to dwellings at no cost to homeowners and renters that met income requirements. Both the Rebate and Weatherization programs required participants to undergo both an as-is energy efficiency audit before any energy efficiency improvements were made to the home and a post-improvement energy efficiency audit after energy efficiency improvements were completed. During the energy efficiency audit, a home was assigned an energy efficiency rating on a scale ranging from 1 Star for the least energy efficient homes to 6 Stars for the most energy efficient homes. Homes that sold after the date of their post-improvement audit were assigned their post improvement energy ratings. Homes that sold before the date of their as-is energy audit were assigned their as-is energy rating based on two assumptions; first, all else constant, the energy efficiency of a home is unlikely to degrade a great deal over eight years, which is the length of study period, and second, a homeowner is unlikely to pay out-of-pocket to make significant energy efficiency upgrades to a property before applying to an available, publicly-funded residential energy efficiency improvement program.

For both the Fairbanks and Anchorage samples, there were relatively few observations with 1 Star, 1 Star+, 5 Star, and 5 Star+ energy efficiency ratings. No home in either sample had a 6 Star energy efficiency rating. For categories with few observations, outliers and observations with high leverage may have a strong influence on parameter estimates. A robust estimator was used to mitigate the impact of outliers and high-leverage observations on the regression coefficients. Models for the Fairbanks and Anchorage markets were estimated separately.

The Anchorage sample consisted of 4,207 observations. The results indicate that in Anchorage, compared to homes with a 3 Star energy rating, which is the average rating for homes in Anchorage, homes with 3 Star+, 4 Star, 4 Star+, and 5 Star energy efficiency ratings sold for price premiums of 1.8%, 3.1%, 4.6%, and 6.0%, respectively. The premium associated with homes with a 5 Star + energy rating was not statistically significant. Compared to homes with a 3 Star energy rating, homes in the Anchorage market with a 1 Star, 1 Star+, 2 Star, and 2 Star+ homes sold for price discount of 7.4%, 7.7%, 2.6%, and 1.3%, respectively.

The Fairbank sample had 1,371 observations. In the Fairbanks market the average energy efficiency rating for homes was 3 Stars. Compared to homes with an energy rating of 3 Stars, homes with 4 Star, 4 Star+, 5 Star and 5 Star+ energy efficiency ratings sold for price premiums of 6.9%, 9.0%, 17.5%, and 12.7%, respectively. The premium associated with 3 Star+ homes was not statistically significant. Compared to homes with a 3 Star rating, homes with a 1 Star, 1 Star+, 2 Star, and 2 Star+ energy ratings sold at a discount of 13.3%, 12.2%, 12.4%, and 5.0%, respectively.

5.2 Discussion

The results indicate that in both the Fairbanks and Anchorage markets, energy efficient homes sell for a price premium. Previous studies have found a positive relationship between energy efficiency and the transaction price of residential properties. Studies examining the price premium associated with the U.S. Environmental Protection Agency's Energy Star certification in housing markets show that Energy Star certified properties sell for a 1.2% to 4.9% premium in various housing markets across the country (Bruegge et al., 2016; Kahn and Kok, 2014; Walls et al., 2016). Properties with the local green certification command a 3% premium in Portland and between a 7% to 8% price premiums in Austin (Walls et al., 2016). In European housing markets, energy efficient residential properties sell for price premiums between 1.5% and 25% (Chegut et al., 2016; Davis et al., 2015; de Ayala et al., 2016; Fuerst et al., 2016; Hyland et al., 2013). In Singapore, properties with the local GreenMark certification sell for a price premium between 4% and 13% compared to non-certified properties, and when the GreenMark certification is broken out into levels, properties with the highest level of certification, Platinum, sell for a price premium between 14% and 28% compared to non-certified properties (Addae-Dapaah and Chieh, 2011; Deng et al., 2012).The results for the studies on the Fairbanks and Anchorage real estate markets are in accordance with previous studies relating the energy efficiency and transaction prices of residential properties.

According to the AHFC, Rebate participants spent an average of $11,681on energy efficiency improvements to their homes, and received an average rebate of $6,609 in Fairbanks and $7,422 in Anchorage (Ord, 2015). Thus, the average Rebate participant's out-of-pocket costs were $5,072 in Fairbanks and $4,259 in Anchorage. Homes that completed the Rebate program command a price premium between 15.1% and 15.5% in Fairbanks which equates to a price premium between $35,035 and $35,909 at the mean price of a home in the Fairbanks market. Homes completed the Rebate program in Anchorage command a price premium between 5% and 11% which equates to a premium between $15,305 and $34,102 at the mean selling price of a home in the Anchorage market. Thus, the results indicate that the energy efficiency improvements made by Rebate participants are capitalized into the selling price of homes in both Fairbanks and Anchorage markets. The results suggest that even absent the Rebate program, investing in energy efficiency was a prudent investment for homeowners in both the Fairbanks and Anchorage markets because the average price premium paid for homes that underwent an energy efficiency retrofit exceeds the average pre-rebate investment made by Rebate program participants. Although, the results for the studies on how Rebate participation affects transaction prices are specific to Rebate participant homes, the results can be more broadly applied to any home that has undergone and energy efficiency retrofit in the Fairbanks or Anchorage market.

Collectively, the results of these studies indicate that the price premium paid for energy efficient properties is higher in the Fairbanks market than in the Anchorage market. In the Fairbanks market, the price premium paid for homes that have completed the Rebate program is between 15.1% and 15.5% compared to the 5% to 11% price premium paid for homes that have completed the Rebate program in the Anchorage market. Additionally, in Fairbanks, the price premium paid for homes with above-average energy efficiency ratings is between 6.9% and 17.5% compared to the 1.8% to 6.0% price premium paid for properties with above-average energy efficiency ratings in the Anchorage market. These results follow expectations because Fairbanks has both a colder climate and a higher home energy costs than Anchorage. Fairbanks averages 23% more heating degree days than Anchorage, and average residential energy costs in Fairbanks are 2.9 times higher than in Anchorage (ACRC, 2016; AHFC, 2014). Thus, the potential energy cost savings resulting from occupying an energy efficient home in Fairbanks are likely greater than in Anchorage.

There are multiple benefits for those either purchasing an energy efficient home or investing in energy efficiency improvements to a home in the Fairbanks and Anchorage housing markets. Alaskans purchasing an energy efficient home can take advantage of the AHFC's Energy Efficiency Interest Rate Reduction program that offers reduced interest rates on mortgages for homes meeting energy efficiency criteria (AHFC, 2016). The occupants of energy efficient properties have lower household energy costs compared to the occupants of comparable homes with lower energy efficiency ratings. Investing in energy efficiency improvements to a property benefits the occupants immediately through reduced energy cost stemming from the improvements. Lastly, owners of energy efficient properties benefit when they sell their homes because, as the results indicate, energy efficient properties command a price premium in both the Fairbanks and Anchorage residential real estate markets.

5.2.1 Contribution of Research

This research contributes to the growing body of research relating the energy efficiency and transaction prices of homes. More specifically, this research adds to the body of literature focusing on the value of residential energy efficiency in cold climate regions. No other research has been conducted on the impact of participation in the Rebate program or energy efficiency ratings on transaction prices of residential properties in Alaska real estate markets. The results of these studies provide information regarding the value Fairbanks and Anchorage residents place on residential energy efficiency which may be useful to Alaska policymakers responsible for shaping residential energy efficiency policies and programs.

The results of these studies may also be useful to residents of Fairbanks and Anchorage who are considering investing in energy efficiency upgrades to their homes. The cost of energy efficiency upgrades may deter some homeowners, especially if they are unsure of how long they will be occupying a home. Homeowners may be hesitant to invest in energy efficiency improvements if they do not believe they will occupy a property long enough to recoup the capital costs through energy cost savings. The results of the Rebate studies indicate that the capital costs of energy efficiency investments are capitalized into the value of the home. Knowing energy efficient homes in Fairbanks and Anchorage sell at premium may incentivize homeowners who are ambivalent about making energy efficiency upgrades to go forth with the upgrades. Even if the payback period for the energy efficiency upgrades exceed the owner’s tenure in the home, the costs may be recouped through the energy efficiency price premium when the home is sold, depending on the cost of the upgrades.

5.2.2 Limitations of the Current Work

This work could be improved if the energy cost savings resulting from energy efficiency improvements were known. This information is not currently collected. AHFC uses engineering software to estimate the energy savings associated with energy efficiency retrofits. If information on actual energy costs savings were available, it would be possible to determine if the energy costs savings are capitalized into the transaction prices of homes. One would expect the price premium a homebuyer is willing to pay for an energy efficient property to be less than or equal to the present value of their expected energy cost savings over their anticipated tenure in the home. The results of the current research show that energy efficient homes sell for a price premium in Fairbanks and Anchorage, but the results do not address actual energy cost savings resulting from occupying energy efficient properties.

The studies on the impact of the Rebate program in the Fairbanks and Anchorage property markets could be improved if information on the specific energy efficiency improvements made by Rebate participants was available. Unfortunately, the data provided by the AHFC did not include the specific energy efficiency improvements made by homeowners or the costs of those improvements. The results of these studies shows that homes that participated in the Rebate program sell for a price premium, but this premium is an aggregate premium and does not break out the impact of different energy efficiency improvements. If information on specific energy efficiency improvements were available, it would be possible to determine how different energy efficiency measures impact the transaction prices of homes.

The study on the relationship between the energy efficiency rating of homes and their transaction prices in the Fairbanks and Anchorage markets could be improved through the use of a larger sample of homes. Currently the sample only includes homes that eventually applied to either the Rebate or Weatherization program. The purpose of the study is not to determine the impact of either the Rebate or the Weatherization program (less than 40% of each sample had completed either program at the time of sale) but rather to examine how energy efficiency ratings affect the transaction prices of homes. The Rebate and Weatherization data merely provided a sample of homes that had energy efficiency ratings. Many homes in Alaska do not have an energy efficiency rating because many homes have never undergone an energy efficiency audit.

5.2.3 Limitations of the Rebate Program

The goal of the Rebate program was to reduce household energy costs by incentivizing homeowners to invest in energy efficiency improvements. The Rebate program successfully incentivized over 25,000 homeowners across the state to invest in the energy efficiency of their homes, but the program was not without its flaws. The rebate received by a program participant was based on the improvement in the energy rating of their home between the as-is and post-improvement energy audits. The reimbursement levels for increments of improvement were uniform across the state, but the costs associated with increasing the energy efficiency rating of a home were not uniform across state due to variation in average annual heating degree days and the costs of materials needed to make the improvements across communities.

It costs less to increase the energy efficiency rating of a home in Anchorage than it does in Fairbanks. For example, a homeowner in Fairbanks would have to install more insulation to increase the energy efficiency rating of a home than the owner of a comparable home in

Anchorage because it is colder in Fairbanks than in Anchorage (Waterman, 2017). This means Rebate participants with homes located in colder regions of the state were at a relative disadvantage to Rebate participants with homes located in relatively warmer regions because they were required to spend more money to achieve a comparable improvement in their energy efficiency ratings.

Homeowners located in communities off the road system were at a relative disadvantage to homeowners located in communities on the road system because communities without road access must rely on barges or airplanes to deliver materials resulting in high shipping costs for materials needed to make energy efficiency improvements. The additional shipping costs add to the cost of materials. Because material costs are higher in communities off the road system, it is more expensive to make improvements to a home in an off-road community than to make the same improvements to a home in an on-road community, which likely contributed to the low participation rate for the Rebate program in rural communities. Other factors contributing to the low participation rate in the Rebate program in rural communities include lack of available qualified energy raters to complete energy audits, lack of available private contractors to complete the energy efficiency improvements, lower median household income compared to more urban areas, a shorter construction season, and inflexible shipping schedules (Dodge et al., 2012).

Should the Rebate program be reinstated in the future, regional differences in heating degree days and construction costs should be taken into consideration when determining reimbursement levels for increments of improvement in energy efficiency ratings. Communities located in colder regions and off-road communities should be eligible for greater reimbursement since it costs more to improve the energy efficiency ratings of homes in these communities compared to communities with warmer climates or communities on the road system.

Another limitation of the Rebate program was that Rebate program participants had no incentive to submit receipts for materials and labor beyond $10,000 because the maximum possible rebate amount was $10,000 (Goldsmith et al., 2012). Therefore, the AHFC does not know the exact amount homeowners invested in their energy efficiency retrofits. It would be beneficial to have this information to conduct a precise cost benefit analysis of the program. Should the program be reinstated, one way to incentivize homeowners to turn in all receipts is to implement a raffle. The state could incentivize homeowners to turn in all receipts for materials and labor by informing participants that a certain number program participants per year, ten for example, would be randomly selected to have all of their qualified costs reimbursed. It is unlikely that a homeowner would spend far in excess of the maximum possible rebate because the probability of being selected is small. However, the small probability of being selected would provide program participants extra incentive to submit all receipts for qualified costs.

5.3 Recommendations for Future Work

Future research should focus on the actual energy savings associated with energy efficiency retrofits. The use of a DiD analysis would allow researchers to calculate the effect of energy efficiency improvements on household energy costs by comparing the average change over time in household energy costs for a treatment group of homes that received energy efficiency improvements, compared to the average change in household energy costs over time for a control group of homes that did not receive energy efficiency improvements. Studies of this nature would be especially valuable in regions of the state with very high energy costs such as rural areas where diesel fuel is used for electricity generation and space heating.

A study investigating how specific energy efficiency measures undertaken by homeowners affect the transaction prices of homes should be conducted in the future. The results of the current research show that energy efficient properties sell for a price premium, but do not break out the specific energy efficiency measures that contribute to a home's energy efficiency. The results of such a study would provide useful information to homeowners wishing to maximize the value of their energy efficiency investments.

In the future, hedonic analyses relating residential energy efficiency and transaction prices should be conducted for other Alaska housing markets such as the Matanuska-Susitna Borough and the City and Borough of Juneau housing markets. In order to increase the sample size for future studies, transactions in the MLS database should be matched to all of the homes in the AkWarm database, instead of only the homes that participated in the Rebate and Weatherization programs.

Now that the Rebate program has been suspended, an updated cost benefit analysis covering the entire lifespan of program should be conducted that builds on previous studies of the Rebate program (Dodge et al., 2012; Goldsmith et al., 2012; Information Insights, 2009). There are several different ways of assessing the costs and benefits of the program depending on what is included in the assessment. One could use the private costs (based on the receipts participants turned into the AHFC), public costs, or the combined private and public costs to assess the program. Regarding the benefits, there are multiple benefits associated with the program in addition to energy cost savings. For example, increased home values, increased property tax revenue for the boroughs, reduced CO_2 emissions, reduced particulate matter emissions, and increased economic activity in the construction sector are all benefits associated with the Rebate program (Dodge et al., 2012; Goldsmith et al., 2012). In order to conduct a cost benefit analysis, one would need to calculate the value of all the benefits associated with the Rebate program. Using the estimated average energy consumption by energy rating for Anchorage and Fairbanks homes in the Alaska Retrofit Information System (ARIS) database and the results from this dissertation regarding the value of energy efficiency, it is possible to estimate energy savings, energy cost savings, and CO_2 emissions savings associated with the Rebate program as well as the aggregated equity that accrued to homeowners that sold their homes after completing the Rebate program. Using property tax records it would be possible to determine how the Rebate program affected property tax revenue. The reduction in particulate matter emissions and increased economic activity stemming from the Rebate program would be more difficult to measure.

Total energy savings resulting from households participating in the Rebate program in the Anchorage and Fairbanks markets can be estimated based on the average per square foot energy use for homes by energy efficiency rating in the ARIS database. In order to calculate each household's energy savings, one would need to know each household's as-is energy rating, post-improvement energy rating, date of the post-improvement energy rating, fuel used for heating, and square footage of the home. First calculate the per square foot British thermal unit (Btu) energy savings between the as-is energy rating and the post-improvement energy rating separately for heat and electricity. Then multiply the per square foot Btu savings for heat and electric by the square footage of the house to get the total Btu saved for heat and the total Btu saved for electric. Then divide the total Btu saved for heat by the Btu in a unit of the heating fuel used to heat the home, and divide the total Btu saved for electricity by 3,412, which is the Btu in a kilowatt hours (kWh) of electricity. This will yield the units of heating fuel and kWh saved annually. Next subtract the current date from the date of the post-improvement energy audit to determine the number of years since the household underwent the energy efficiency retrofit. Multiply the annual heating and electricity energy savings by the number of years since the household underwent the retrofit to determine total heating and electricity savings for each household. Then sum across all participant households to determine the total program heating and electricity savings. Table 5.1 and Table 5.2 respectively show annual heat savings and electric savings associated with increasing the energy efficiency rating for the average-sized Anchorage home in the ARIS database. Table 5.3 and Table 5.4 respectively show the annual heat and electric savings associated with increasing the energy efficiency rating for the average-sized Fairbanks home in the ARIS database.

Total energy cost savings resulting from Rebate program participation can be estimated using a similar method as the one described in the previous paragraph. After calculating the units of heating fuel and kWh saved annually for each year since a home completed the program, the units are multiplied by the average inflation-adjusted price of fuel for the given year. Then annual cost savings are summed across all years for all participant households to determine the total program energy cost savings. Table 5.5 and Table 5.6 show the annual cost savings at current energy prices for the average-sized home in the ARIS database for Anchorage and Fairbanks, respectively.

Total CO_2 emissions reductions resulting from the Rebate program can be estimated using the average CO_2 emissions by energy efficiency rating for homes in the ARIS database. First the difference between the average annual CO_2 emissions for a home's as-is energy rating and post-improvement rating is calculated. Then the savings are summed over the number of years since the home underwent the energy efficiency retrofit. Then the CO_2 emissions savings are summed across all participants yielding total emissions reductions associated with Rebate program participation. A monetary value must be assigned to CO_2 emissions reductions in order to include the reductions in a cost benefit analysis. CO_2 emissions reductions associated with increasing the energy efficiency rating of a home in Anchorage and Fairbanks are displayed in Tables 5.7 and Tables 5.8, respectively.

The results of the analysis in Chapter 3 and Chapter 4 indicate that homes that completed the Rebate program in the Anchorage and Fairbanks markets sold at a price premium compared to similar properties that did not complete the program. It is possible to estimate the aggregate equity that accrued to those who sold their homes after participating in the Rebate program if one assumes that all participants sold their home for the mean transaction price in their respective market.

In the Anchorage real estate market, the average price premium for Rebate program participants is between 5% (DiD estimate) and 10% (PSM sample estimate) and the average transaction price is between $306,107 (repeat sale sample) and $341,019 (PSM sample). Therefore, the Rebate program participation created between $191 million and $426 million in equity for Anchorage homeowners. The average rebate for an Anchorage participant and was $7,422 and 12,478 Anchorage homeowners completed the Rebate program. Thus, the state invested approximately $92 into the Anchorage housing stock through the Rebate program. The total equity created through participating in the program far exceeds the amount invested in the program by the state in the Anchorage market.

In the Fairbanks real estate market, the average price premium for Rebate program participants is 15.1% (PSM sample estimate) and the average transaction price is $232,020 (PSM sample). Therefore, Rebate program participation created approximately $108 million in equity for Fairbanks homeowners. The average rebate for a Fairbanks participant was $6,378 and 3,069 homeowners completed the Rebate program. Therefore, the state invested approximately $20 million into the Fairbanks housing stock through the Rebate program. The total equity created through participating in the Rebate program exceeds the state's investment in the program in the Fairbanks market.

The Rebate program incentivized participants to invest in energy efficiency improvements for their homes leading to an improved housing stock. As the housing stock improves, its overall value increases leading to increased property tax revenue for the boroughs. To determine if Rebate program participation lead to increased property tax revenue, a study could be conducted where the property taxes of all homes that sold in each borough from 2008 through 2015 are recorded for the year prior to their the sale and the year after their sale. Any differences in the mill rates for road service areas need to be taken into account and adjusted for accordingly. Then a DiD analysis could be conducted with Rebate participants as the treatment group and non-Rebate participants as the control group to determine if the Rebate program significantly increased property tax revenue.

Although the Rebate program has been suspended, it is useful to determine the threshold price of heating fuel needed to justify a homeowner investing $10,000 in the thermal efficiency of their home based on the average energy use of homes by energy efficiency rating in the ARIS database. First the difference in average per square foot energy use for heating between the home's current energy rating and target energy rating is calculated yielding the per square foot

Btu energy savings. The per square foot Btu energy savings are multiplied by the square footage of the home yielding the total Btu savings. Then the total Btu savings are divided by the Btu in a unit of heating fuel yielding the total units of heating fuel saved annually. The annual total is multiplied by five yielding the total units saved over a five year period. Then the $10,000 investment is divided by the total units saved over a five year period yielding the threshold per unit price of fuel needed to justify a $10,000 investment in the thermal efficiency of a home. Table 5.9 and Table 5.10 show the threshold price of fuel needed to justify investing $10,000 in thermal efficiency improvements to a home assuming a five year simple payback period in Anchorage and Fairbanks, respectively.

5.4 Conclusion

Residential energy efficiency is an important topic in Alaska housing markets because of the state's cold climate and relatively high energy prices. This dissertation comprises three studies relating energy efficiency to the transaction prices of homes in Alaska real estate markets. The results indicate that there is a positive relationship between the energy efficiency of a home and its transaction price, and homebuyers in the Fairbanks and Anchorage housing markets are willing to pay a price premium for energy efficient dwellings. However, both the energy costs savings resulting from energy efficiency improvements and the effects of specific energy efficiency improvements on the transaction price of homes are unknown. Future studies should measure the energy cost savings resulting from energy efficiency improvements to homes and attempt to disaggregate the energy efficiency price premium. Also, future studies should be conducted on other housing markets throughout Alaska to gain a more complete understanding of how Alaska residents value residential energy efficiency. Lastly, an updated cost benefit analysis of the Rebate program should be conducted to assess the overall value of the program.

5.5 References

ACRC (Alaska Climate Research Center), 2016. Climate normal. http://climate.gi.alaska.edu/ClimTrends/Change/TempChange.html (accessed 19.12.16).

Addae-Dapaah, K., Chieh, S. J., 2011. Green mark certification: Does the market understand? Journal of Sustainable Real Estate 3(1), 162-191.

AHFC (Alaska Housing Finance Corporation), 2016. Energy efficiency interest rate reduction. https://www.ahfc.us/efficiency/energy-programs/energy-efficiency-rate-reduction/ (accessed 06.07.16).

AHFC (Alaska Housing Finance Corporation), 2014. Alaska Housing Assessment. https://www.ahfc.us/efficiency/research-information-center/housing-assessment/ (accessed 03.04.16).

Boardman, B., 2010. Fixing fuel poverty: Challenges and solutions. Earthscan, New York.

Brehmer, E., 2016. Budget deficit hits state energy programs, rebates cut. Alaska Journal of Commerce. http://www.alaskajournal.com/2016-03-02/budget-deficit-hits-state-energy-programs-rebates-cut#.V-czn6L-R4O (accessed 01.09.16)

Bruegge, C., Carrión-Flores, C., Pope, J.C., 2016. Does the housing market value energy efficient homes? Evidence from the energy star program. Regional Science and Urban Economics 57, 63-76.

Chegut, A., Eichholtz, P., Holtermans, R., 2016. Energy efficiency and economic value in affordable housing. Energy Policy 97, 39-49.

Davis P.T., McCord, J., McCord, M.J., Haran, M., 2015. Modeling the effect of energy performance certificate rating on property value in the Belfast housing market. International Journal of Housing Markets and Analysis 8(3), 292-317.

de Ayala, A., Galarraga, I., Spadaro, J.V., 2016. The price of energy efficiency in the Spanish housing market. Energy Policy 94, 16-24.

Deng, Y., Li, Z., Quigley, J.M., 2012. Economic returns to energy-efficient investments in the housing market: Evidence from Singapore. Regional Science and Urban Economics 42, 506-515.

Dodge, K., Wiltse, N., Valentine, K., 2012. Home Energy Rebate program outcomes. Cold Climate Housing Research Center.

Fuerst, F., Oikarinen, E., Harjunen, O., 2016. Green clientele effects in the Helsinki metropolitan area housing market, City of Helsinki Urban Facts Working Papers 2016:3.

Goldsmith, S., Pathan, S., Wiltse, N., 2012. Snapshot: the home energy rebate program. Institute of Social and Economic Research, University of Alaska Anchorage. http://cchrc.org/docs/snapshots/HERP_snapshot.pdf (accessed 13.09.16).

Hyland, M., Lyons, R.C., Lyons, S., 2013. The value of domestic building energy efficiency: Evidence from Ireland. Energy Economics 40, 943-952.

Information Insights, 2009. Alaska housing assessment: Part I and II. http://www.cchrc.org/docs/reports/TR_2009_02_2009_AK_Housing_Assessment_Final.pdf (accessed 01.09.16)

Kahn, M.E., Kok, N., 2014. The capitalization of green labels in the California housing market. Regional and Urban Economics 47 (2014) 25-34.

Ord, J., 2015, January 27. Committee minutes. Alaska State Legislature House Special Committee on Energy. http://www.legis.state.ak.us/basis/get_single_minute.asp?session=29&house=H&comm=ENE&date=20150127&time=1019 (accessed 23.09.16).

Walls, M., Palmer, K., Gerarden, T., Bak, X., 2016. Is energy efficiency capitalized into home prices? Evidence from three U.S. cities. Resources for the Future, working paper.

Waterman, S., 2017, March 16. Alaska Housing Finance Cooperation State Energy Program Manager, e-mail message to author.

Table 5.1. Annual fuel savings (Mcf) associated with increasing the energy efficiency rating of an Anchorage home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	86									
2 Star	144	58								
2 Star+	202	116	57							
3 Star	242	156	97	40						
3 Star+	281	195	137	80	40					
4 Star	322	236	177	120	80	40				
4 Star+	349	263	205	148	108	68	28			
5 Star	381	295	237	179	139	100	59	32		
5 Star+	408	322	263	206	166	126	86	58	27	
6 Star	443	357	299	241	201	162	121	94	62	35

* Calculations based on a 2,177 square foot home which is the average-sized home in ARIS database for Anchorage and 1,032,000 Btu/Mcf of natural gas.

Table 5.2. Annual fuel savings (kWh) associated with improving the energy efficiency rating of an Anchorage home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	4747									
2 Star	7297	2550								
2 Star+	8138	3391	841							
3 Star	8188	3442	892	51						
3 Star+	8386	3640	1090	249	198					
4 Star	8700	3953	1403	562	511	313				
4 Star+	8835	4089	1539	697	647	449	136			
5 Star	8916	4170	1620	778	728	530	217	81		
5 Star+	9498	4752	2202	1360	1310	1112	799	663	582	
6 Star	10448	5701	3151	2310	2259	2061	1748	1612	1531	949

* Calculations based on a 2,177 square foot home which is the average-sized home in ARIS database for Anchorage and 3,412 Btu/ kwh of electricity.

Table 5.3. Annual fuel savings (gallons) associated with increasing the energy efficiency rating of a Fairbanks

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	351									
2 Star	851	499								
2 Star+	1166	815	316							
3 Star	1486	1134	635	319						
3 Star+	1707	1355	856	541	221					
4 Star	1903	1552	1053	737	417	196				
4 Star+	2136	1784	1285	970	650	429	233			
5 Star	2369	2017	1518	1202	883	662	465	233		
5 Star+	2580	2229	1730	1414	1095	874	677	445	212	
6 Star	2759	2407	1908	1593	1273	1052	856	623	390	178

*Calculations based on a 2,163 square foot home which is the average-sized home in ARIS database for Fairbanks and 138,000 Btu/gallon of #2 heating fuel oil.

Table 5.4. Annual fuel savings (kWh) associated with improving a the energy efficiency rating of a Fairbanks home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	10906									
2 Star	14058	3151								
2 Star+	15292	4386	1235							
3 Star	16665	5759	2608	1373						
3 Star+	17601	6695	3544	2309	936					
4 Star	18819	7913	4761	3527	2154	1217				
4 Star+	19834	8928	5777	4542	3169	2233	1015			
5 Star	20501	9595	6444	5209	3836	2900	1683	1015		
5 Star+	19299	8393	5242	4007	2634	1698	480	1683	-1202	
6 Star	19121	8215	5064	3829	2456	1520	302	480	-1380	-178

* Calculations based on a 2,163 square foot home which is the average-sized home in ARIS database for Fairbanks and 3,412 Btu/ kwh of electricity. Note that average Btu/square foot increases for 5 Star and 5 Star+ homes most likely due to the installation of heat recovery ventilators.

Table 5.5. Annual energy cost savings (USD) at current energy prices associated with increasing the energy efficiency rating of an Anchorage home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	1621									
2 Star	2609	988								
2 Star+	3301	1680	693							
3 Star	3695	2075	1087	394						
3 Star+	4109	2489	1501	808	414					
4 Star	4552	2931	1943	1251	857	443				
4 Star+	4842	3221	2233	1541	1146	732	290			
5 Star	5159	3538	2551	1858	1464	1050	607	317		
5 Star+	5514	3893	2905	2213	1819	1405	962	672	355	
6 Star	6012	4392	3404	2711	2317	1903	1460	1171	853	498

* Calculations based on a 2,177 square foot home which is the average-sized home in ARIS database for Anchorage, 16.67 cent/ kwh electricity, and $9.64/Mcf natural gas.

Table 5.6. Annual energy cost savings (USD) at current energy prices associated with increasing the energy efficiency rating of a Fairbanks home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	3100									
2 Star	5050	1950								
2 Star+	6132	3031	1082							
3 Star	7251	4151	2201	1120						
3 Star+	8024	4924	2974	1892	773					
4 Star	8786	5686	3736	2654	1535	762				
4 Star+	9605	6505	4555	3473	2354	1581	819			
5 Star	10354	7254	5304	4223	3103	2330	1568	749		
5 Star+	10677	7576	5627	4545	3425	2653	1891	1072	323	
6 Star	11113	8013	6064	4982	3862	3089	2327	1508	759	437

* Calculations based on a 2,163 square foot home which is the average-sized home in ARIS database for Fairbanks, 19.89 cent/ kwh electricity, and $2.65/gallon of #2 heating fuel oil.

Table 5.7. Annual CO_2 emissions reductions associated with increasing the energy efficiency of an Anchorage home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	6794									
2 Star	9305	2511								
2 Star+	11891	5097	2586							
3 Star	15260	8466	5954	3368						
3 Star+	18516	11722	9211	6625	3257					
4 Star	22269	15475	12964	10378	7010	3753				
4 Star+	25371	18577	16066	13480	10112	6855	3102			
5 Star	27434	20640	18129	15543	12175	8918	5165	2063		
5 Star+	30163	23369	20858	18272	14904	11647	7894	4792	2729	
6 Star	33342	26548	24036	21450	18082	14826	11072	7970	5907	3179

* Calculations based on average emissions reductions by energy rating for Anchorage homes in the ARIS database

Table 5.8. Annual CO_2 emissions reductions associated with increasing the energy efficiency of a Fairbanks home

Rating	1 Star	1 Star+	2 Star	2 Star+	3 Star	3 Star+	4 Star	4 Star+	5 Star	5 Star+
1 Star										
1 Star+	10407									
2 Star	17743	7335								
2 Star+	20937	10530	3195							
3 Star	26063	15656	8321	5126						
3 Star+	29586	19178	11843	8648	3522					
4 Star	34344	23937	16602	13407	8281	4759				
4 Star+	38689	28281	20946	17751	12625	9103	4344			
5 Star	42883	32476	25141	21946	16820	13298	8539	4195		
5 Star+	51471	41064	33728	30534	25408	21885	17127	12782	8588	
6 Star	55266	44858	37523	34328	29202	25680	20921	16577	12382	3795

* Calculations based on average emissions reductions by energy rating for Fairbanks homes in the ARIS database

Table 5.9. Threshold price a Mcf of natural gas to justify a $10,000 investment in the thermal efficiency of an Anchorage home assuming a 5 year simple payback period

Rating	1 Star	1 Star +	2 Star	2 Star +	3 Star	3 Star +	4 Star	4 Star +	5 Star	5 Star +
1 Star										
1 Star +	23.24									
2 Star	13.85	34.26								
2 Star +	9.91	17.29	34.91							
3 Star	8.27	12.85	20.55	49.98						
3 Star +	7.11	10.25	14.62	25.15	50.60					
4 Star	6.22	8.49	11.28	16.66	25.00	49.39				
4 Star +	5.72	7.59	9.75	13.54	18.56	29.32	72.15			
5 Star	5.25	6.78	8.45	11.16	14.36	20.05	33.76	63.44		
5 Star +	4.91	6.22	7.60	9.71	12.05	15.81	23.26	34.32	74.78	
6 Star	4.51	5.60	6.70	8.29	9.94	12.36	16.49	21.38	32.24	56.69

* Calculations based on a 2,177 square foot home which average-sized home in ARIS database for Anchorage, a $10,000 investment, and a five year simple payback period.

Table 5.10. Threshold price a gallon of #2 heating fuel oil to justify a $10,000 investment in the thermal efficiency of a Fairbanks home assuming a 5 year simple payback period

Rating	1 Star	1 Star +	2 Star	2 Star +	3 Star	3 Star +	4 Star	4 Star +	5 Star	5 Star +
1 Star										
1 Star +	5.69									
2 Star	2.35	4.01								
2 Star +	1.72	2.45	6.34							
3 Star	1.35	1.76	3.15	6.26						
3 Star +	1.17	1.48	2.34	3.70	9.04					
4 Star	1.05	1.29	1.90	2.71	4.79	10.19				
4 Star +	0.94	1.12	1.56	2.06	3.08	4.66	8.59			
5 Star	0.84	0.99	1.32	1.66	2.27	3.02	4.30	8.60		
5 Star +	0.78	0.90	1.16	1.41	1.83	2.29	2.95	4.50	9.44	
6 Star	0.73	0.83	1.05	1.26	1.57	1.90	2.34	3.21	5.13	11.23

* Calculations based on a 2,163 square foot home which average-sized home in ARIS database for Fairbanks, a $10,000 investment, and a five year simple payback period.